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DRAINAGE
AND
SANITATION

DRAINAGE AND SANITATION

By

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PREFACE TO THE ELEVENTH EDITION

The new edition of this well-known text-book has been entirely revised by Leonard B. Gumbrell, A.R.I.C.S., F.A.I., M.R.San.I., Dip.San.Sci.S.I., and J. Francis Smith, F.R.I.B.A., F.R.I.C.S. Much new information is included and matter which appeared in the previous edition has been brought entirely up to date.

The illustrations have been entirely redrawn and have been increased in number.

The authors and publishers wish to thank, amongst others, Mr. L. G. Skelton, A.R.I.B.A., M.R.P.H., for his many helpful comments and suggestions.

Summer, 1956. *B. T. BATSFORD LTD*

PREFACE TO THE FIRST EDITION

Intended primarily as an introduction to the subject, it is hoped that the following pages may prove of interest to both the novice and the experienced practitioner.

There are many conditions which a really healthy building should fulfil. It should, for example, be placed in hygienic surroundings, be well built, free from damp, well planned, ventilated, warmed and lighted, have an efficient water supply and good sanitary fittings, be well drained, and be kept free from accumulations of refuse. An attempt has been made to deal with the subject in a systematic manner. Thus, in the case of water supply, the matter is started at the various sources of supply, traced to the point of distribution, and laid on to the house.

Then follow the sanitary fittings and waste pipes, through which the fouled water leaves the house and enters the drainage. From the drains one goes on to the sewers, and from them, to the works for the disposal of sewage.

An attempt has also been made to avoid continued reference to manufacturers' specialities, which too often gives text-books on this subject the appearance of trade catalogues, and to give types rather than exact reproductions of makers' goods.

July, 1913. *E. H. BLAKE*

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CHAPTER I

Introductory

Need for Practical Study. In a subject such as this, dealing so largely with appliances and fittings in daily use in the home and other buildings, the student has excellent opportunities of combining practical investigations with book knowledge. In spite of a daily familiarity, the average adult, asked to give the height of an ordinary W.C. seat or the dimensions of an average lavatory basin and the height at which it is fixed from the floor, will give some quite surprising figures.

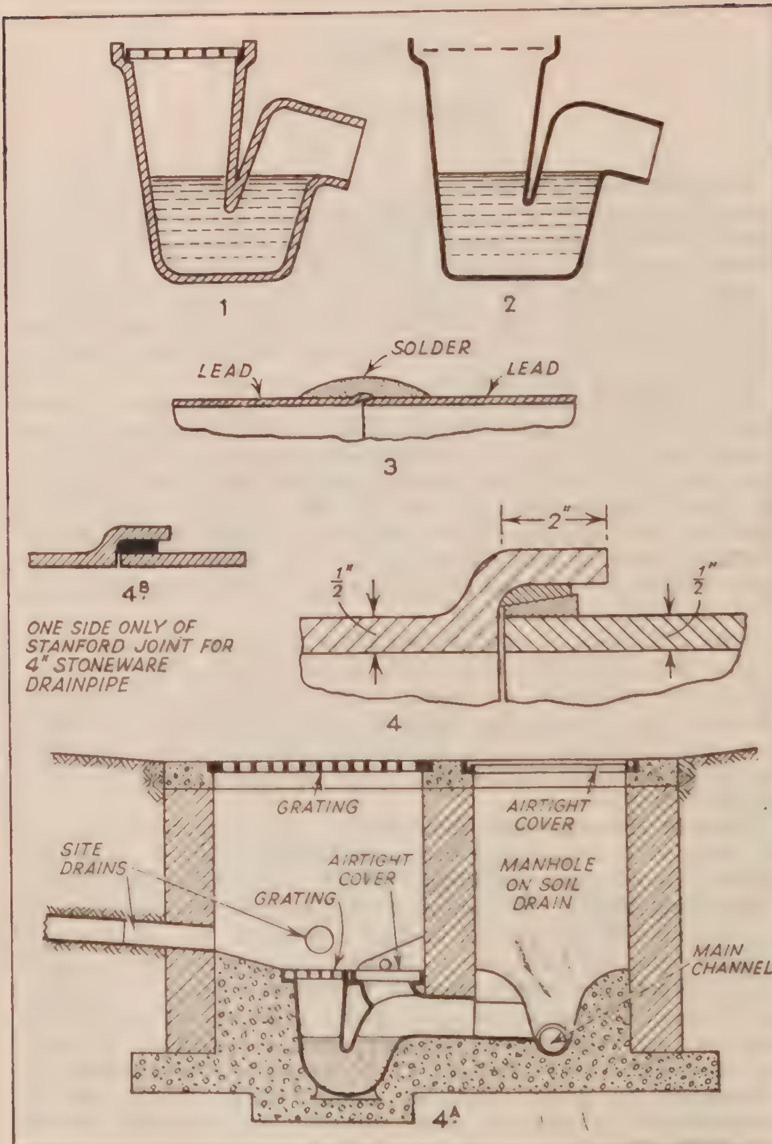
Use of Sketch Book. The student, during his studies, should therefore not just sketch these familiar objects and arrangements from memory, or copy illustrations, but work from actual observation with a two-foot rule or tape measure and a sketch-book in his hand. Information gathered in this way and co-ordinated with the text-book statements will make a lasting impression on his mind, standing him in good stead in any examinations he may have to take in the subject and remaining as part of his professional stock-in-trade in after years.

Some examples of sanitary work are not quite so easy to see in the daily round, but time and trouble taken in lifting off manhole covers of drains, in visiting sites of buildings in course of erection when drains are being laid, in watching fittings being fixed and connected to the drains and soil pipes and inspecting the fixing of water-supply and waste pipes and similar matters will be well repaid.

Visits to Museums and Showrooms. Much practical help can be obtained in most large towns by visiting sanitary museums, makers' showrooms, "building centres" or building exhibitions.

Sketching Ability. The ability to sketch freehand or with simple instruments like setsquares, in such a way that the proportions, without being to scale, are reasonably correct, is also an asset. The architectural student generally has natural aptitude for drawing, fostered by the nature of his training, but many students in associated professions need to study sanitation without this aptitude and a few words of advice to them may not come amiss.

Freehand or Scale. Sketches made during study and in examinations (except when scale drawings are asked for) should


1
2
SOLDER
LEAD
LEAD
3
2"
1/2"
1/2"
4
4B
ONE SIDE ONLY OF STANFORD JOINT FOR 4" STONEWARE DRAINPIPE
GRATING
AIRTIGHT COVER
SITE DRAINS
AIRTIGHT COVER
GRATING
MANHOLE ON SOIL DRAIN
MAIN CHANNEL
4A

aim at showing the essential principles of design and the general proportions should be kept as accurate as possible, even though the work is drawn freehand and without a scale. The probability is that the student will have many other subjects of study in hand at the same time, thus limiting the time available for the individual subject, and every effort should be made to simplify the work and speed up its execution. Often, a single pencil outline, drawn lightly at first and subsequently thickened, will serve to show the section of fitting, without spending time and pains in producing two parallel lines to represent the thickness of the material of which the fitting is made. (Compare Figs. 1 and 2.) Nevertheless, when giving an enlarged detail to show how the joints between the fitting and the drains or water supply are made, it will probably be necessary to show the relative thickness of the different materials involved and the double lines must be used, as in Fig. 3.

Use of Coloured Pencils. Sometimes the use of coloured pencils or crayons will help the student to make his sketches clear to himself, either at the time or during later revision. Even in the examination room, the discriminate use of coloured pencils or crayons will help by making the students' intentions clearer and may save time by reducing the number of lines which need be drawn, but care must be taken not to make the sketches an end in themselves or to spend longer in preparing them than the questions warrant.

Size of Sketches and Diagrams. Size is another point to be considered. The average student starts off by making his sketches far too small. This error doubtless partly stems from the study of text-book illustrations, which are necessarily shown to a small scale for economy's sake and to keep the printed page to a convenient size. Figs. 4b and 4 illustrate this point. Fig. 4, the larger sketch, can be drawn more quickly and illustrates the method of doing the work much more clearly than the smaller sketch, Fig. 4b.

Use of Guide Lines. As regards shape and proportion, the student may be referred back to his schooldays, when he was probably taught to draw a symmetrical vase from a model by the process shown in Figs. 5, 6 and 7. The vertical line forms the backbone of a skeleton or framework, from which dimensions and proportions may be built up by the process shown in Figs. 5 and 6.

Water Level as a Guide Line. Few of the examples to be sketched in sanitation are symmetrical, and some base-line other than the vertical will be found more convenient. In most trapped

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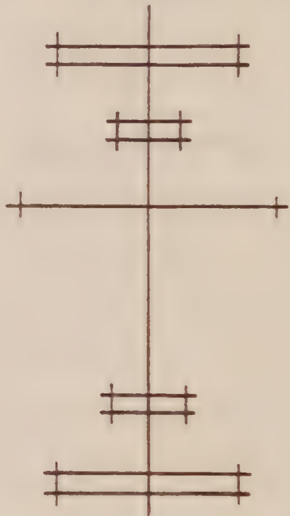

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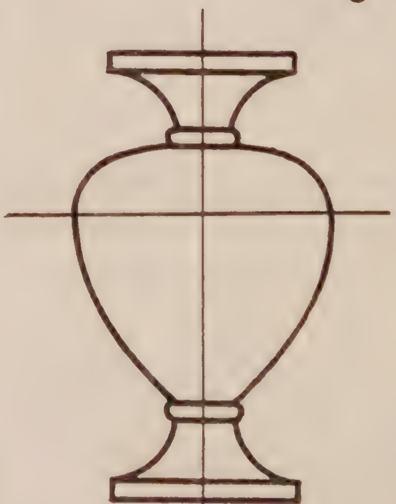

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fittings, the water line is extremely important and the water level may well be put in first and extended right and left to form a base-line, as in Figs. 8, 9 and 10, which show a useful method of sketching the common "S" trap. With small modifications this can also be applied to the sketching of the "½S" and "¾S" traps.

The student should keep in mind that most traps are basically just bent pipes, and the diagrams simply show a longitudinal section through from back to front. The depth of the seal is important (the most usual in practice being 2 inches) so this is sketched in next, and sets an approximate scale, so that the other proportions may be kept fairly true. A little practice by the student will soon enable him to draw the invert (or curved base) of the trap parallel to the seal, and to finish off the inlet and outlet in parallel straight lines to form a workmanlike sketch as shown.

The same idea can be used as a basis to build up a sectional sketch from back to front of a modern washdown W.C. pan, as shown in Figs. 11, 12 and 13.

In this case, too, the depth of seal marks a useful guide to height of flushing rim above water level, the width of the flushing rim, the diameter of the outlet, the dimensions from front of pan to the water-supply inlet, the total height from flushing rim to floor level and so on.

Even the intercepting trap (intercepting sewer air from house drains), which many students find very difficult to draw freehand and in correct proportions, can be drawn true to shape and in fairly accurate proportions by following this method, as may be seen from Figs. 14, 15 and 16.

These few hints may perhaps set the student on the right lines in devising his own ways of keeping his shapes right and his proportions reasonably true.

Figuring on Dimensions. A few leading dimensions figured on, will help him to right ideas of size and will certainly gain better marks in the examination room.

British Standard Designs. The British Standards Institution exists to standardise specifications and goods in many trades for the benefit of manufacturers and consumers. The Institution has been particularly busy in the Building Trade getting together a series of standard specifications for building materials, sorting out and selecting sound standard designs for fittings used in buildings, and so reducing the number of types and designs which the manufacturer needs to produce, the middleman to handle

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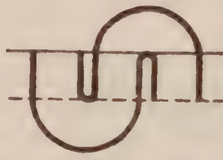

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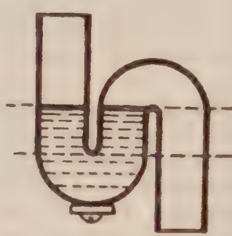

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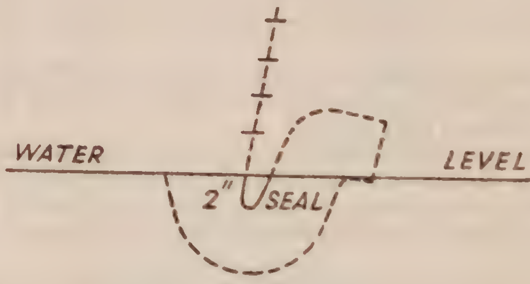

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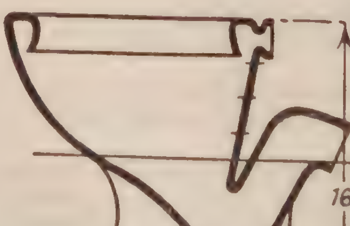

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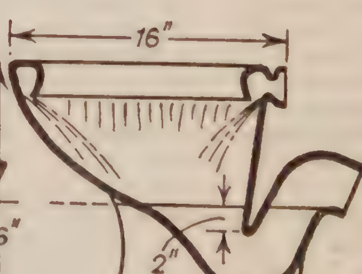

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and store and doing a good deal to simplify the work of the builder and architect.

Another reason why these standard specifications are important is that so many local authorities, in their local building and drainage by-laws, when specifying what they require for a particular case, add a note that the by-law in question "shall be deemed to be satisfied" if the British Standard fitting is used or if the British Standard Code of Practice is followed.

The work of the Institution will be referred to at greater length later on in this volume. Tentative mention is made now to draw attention to the wealth of detail in these standardised designs.

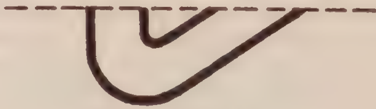
Unlike the manufacturer's draughtsman, who has to turn out working drawings in great detail for the craftsman to follow, the general student will no doubt prefer to produce for himself simplified designs, based on the British Standard models and keeping the general proportions true to shape but with considerably less detail.

The architectural student is in a different category, and spends a good deal of his time turning out working drawings to scale in such a way that the builder or contractor can understand exactly what he is expected to put into the projected building, and he may therefore sometimes find it an advantage to check up his drawings by referring to the British Standard Specification (B.S.S.) in question in a technical library or his firm's bookshelf.

British Standard Codes of Practice. In addition to the British Standard Specifications, there is also a series of "British Standard Codes of Practice" prepared by the Council for Codes of Practice for Building Construction and Engineering Services and which are also published by the British Standards Institution.

These are particularly helpful to the student who wishes to guide his studies into good sound conventional practice, and these codes also will be referred to from time to time in the pages which follow.

Historical Development of Sanitary Fittings. Architectural students and others whose work will be concerned mainly with the erection of new buildings may wonder why so much space in the ensuing pages is given up to the historical development of sanitary fittings and arrangements, rather than restricting the work to the most efficient and up-to-date types. This is done designedly because many readers, particularly those intending to enter the offices of auctioneers and estate agents, surveyors and valuers in general practice and municipal surveyors, will find that their work will include the inspection and upkeep of older buildings



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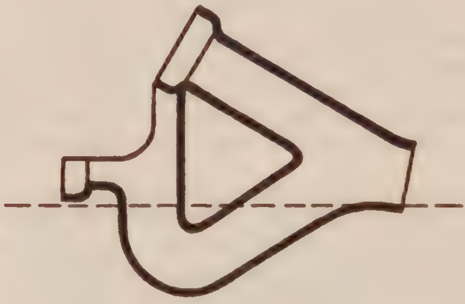

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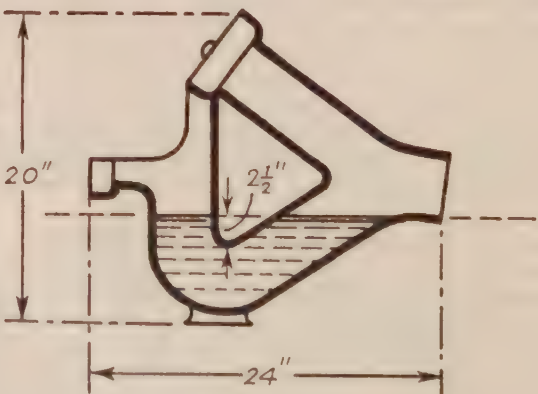

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and reports to intending purchasers or occupiers on the structure and sanitation of buildings of varying ages. Indeed, in practice, sanitary surveys and reports are far more likely to be called for in connection with old property, provided with outmoded or insanitary types of sanitary fittings, than with new or recently built property, and the professional man must know how to assess the shortcomings of the old as well as to appraise the principles of design of efficient modern fittings. Questions set by the examiners naturally reflect the conditions in the professions for which they examine.

CHAPTER II

THE BUILDING—ITS ENVIRONMENT

It has been said that "Governments may stamp the manners, but it is the air they breathe that moulds the form, temper, and genius of a people."

Effect of Climate. In selecting a situation for a house, commercial and economic considerations prevent this point being considered in its broadest sense. The question of climate is one, however, that must, theoretically at any rate, be considered as one of the many points to be taken into account in determining a healthy situation.

Some of the old philosophers have written largely on the influence of climate on race. Vitruvius was one of the first to point out the greater physical and mental endowment of the inhabitants of some countries than of those of others.

Perfection in the arts and sciences hardly ever appears in very high or very low latitudes. In these extremes, it has been pointed out, the passions are sluggish, and the inhabitants show sterility of thought in their arts and manufactures.

In the temperate zone one finds greater mental and physical energy and enterprise.

The effects of climate are as noticeable in regard to the body as in regard to the mind. In polar regions one finds the inhabitants stunted, short-limbed and stiff-jointed, but in travelling southward one finds them of increased stature and greater perfection of shape and features.

Narrowing down this question of climate, one often finds people varying in disposition with changes of weather, becoming joyful or dejected as the case may be.

Instinct teaches animals to migrate with the changes of season. To a very limited extent one finds man actuated by the same instinct, restrained chiefly by economic and commercial considerations.

It may be said that a man can live in any climate, but he can only do so by ingenuity. That is to say, he takes with him suitable dress, which is merely a mechanical means of preserving his own bodily heat and so forming a portable climate.

Other points bearing upon the selection of a situation for a

house are rainfall, death-rate, local sanitary administration, freedom from nuisances, elevation and aspect of the land.

Effect of Rainfall. When comparatively warm air, more or less laden with moisture, is suddenly chilled, by its ascent into a colder atmosphere, or by its contact with the cold surface of the ground, rain falls. The rainfall varies greatly with the locality. From observations taken over a long period of years, the average rainfall of Great Britain is 36·69 inches. For England and Wales it is 33·76 inches and for Scotland 46·56 inches. The average rainfall is much greater in the West of England than in the East, averaging only about 20 inches in the Eastern Counties. The Lake District is a particularly rainy quarter, as much as 150 inches a year having been recorded there, the whole year's rainfall representing, in other words, a sheet of water 12 feet 6 inches deep.

Humidity. It will not be inopportune to refer here to the subject of humidity. Water evaporates into the air and is held by it to an extent varying with the air's temperature. The relative amount of moisture in the air is described as the degree of humidity. Very humid air is not good for the health. The higher the temperature of the air, the larger the proportion of moisture it will take up. "Saturated air" is air which has absorbed all the moisture it can hold. The average humidity of the air in Great Britain is about 75 per cent.; that is to say, it contains about three-fourths the amount of moisture it could hold. Since the lower the temperature of the air the less the quantity of moisture it will hold, it will be seen that, if the temperature of the air were gradually lowered, a point would be reached at which the quantity of moisture present could only just be held by the air, which would therefore become what is termed "saturated". A further decrease in temperature would lead to the air parting with some of its moisture in one of the many ways in which this is possible, such as rain, mist, dew, or snow. The degree of humidity of the air is calculated from what is termed the dew-point; that is, the temperature at which the air parts with its water. The temperature of the dew-point is determined by means of instruments called hygrometers, a description of which will be found later.

Fogs and Mists. Closely allied to the question of humidity is that of fogs.

The air contains an infinite number of minute particles of solid dust, particles so minute as to be quite invisible to the naked eye except, maybe, when a ray of sunshine enters a darkened room through a chink in a shutter. Fogs are caused by these minute

particles becoming surrounded by watery envelopes when the air gives up its moisture.

White Fog. White fog results from clear air at a high degree of humidity coming into contact with a layer of colder air, as when it flows into "frost pockets" or over low-lying land, where the temperature is lower. The quantity of moisture which the air can hold (at 100 per cent. humidity) then drops and the surplus moisture condenses into tiny droplets—usually around a nucleus of dust—to form mist or white fog, according to density.

"London" Fog. Yellow or London fog, sometimes known as "smog", is similar in origin except that the nucleus consists of carbon particles from soot or smoke emitted from industrial or domestic chimneys, turning the fog an opaque yellow or brownish hue, making the eyes smart and causing the interior of the nostrils to go black with grime. Fortunately this class of fog is becoming rarer in our industrial towns with advances in "Smoke Abatement" legislation and the more scientific use of fuel.

Sea Fog. Sea fog is usually the result of a gentle breeze rolling or drifting warm humid air over a colder area of sea water, when, as before, the droplets of condensed moisture envelop nuclei of dust particles, to drift in clouds or billows of white fog over large tracts of land adjoining (or not far distant from) the coast.

In sea fog the dust particles, of volcanic or other origin, are usually clean and more finely divided and the fog is proportionately wetter and purer.

Scotch Mist. "Scotch mist" is an atmospheric condition more common in Scotland than in other parts of Great Britain and is usually the result of humid air rising up to a level where it meets a cool layer of air, preventing it from rising higher and condensing the water vapour into a wet mist or a very fine drizzle. It is often encountered by an observer who climbs up into high ground, to find himself "up in the clouds", though sometimes atmospheric conditions bring the mist and the clouds down to the lower levels.

High and Low Death Rate. It is often suggested that, in selecting a situation for a house, a locality should be chosen where the death-rate is low, but statistics as to death-rates should be regarded with care, as they can be misleading. For example, take the case of a healthy spa, whose death-rate is increased by the invalids attracted by the health-giving qualities of the area. There is also the question of the age and sex distribution of the population, since it is a well-established fact that women live longer than men. Density of population is another factor which

must not be overlooked in investigating death-rates. Parts of a district may be densely populated, thus facilitating the spread of infection and other evils and causing a high death-rate while the district as a whole may be healthy.

Public Services. These are all now excellent in Great Britain, N. America and much of Scandinavia. One would always choose a district which was well provided for in this respect. Out in the open country this point has not much application, but in a town there should be a public supply of good water, a good system of sewerage and sewage disposal; the scavenging should be properly dealt with, the refuse being cremated; the streets should be wide, well arranged so as to get good ventilation, and should be well lighted.

Artificial Nuisances. Artificial nuisances should of course be avoided. One would not, from choice, erect a house near a factory where an obnoxious trade was carried on, such as chemical works, tanneries, soap works and such establishments; nor would one choose a site adjoining a fever hospital, disinfecting station, cemetery or sewage-disposal works. The methods for the disposal of sewage have made large advances in recent years, and one can safely say that with a thoroughly up-to-date installation there is no danger from such works, but, notwithstanding this, the best of schemes is likely to get out of gear at times, and nuisance, though possibly not danger, from smell might arise occasionally.

It is always desirable to get a good circulation of air around a house. It would therefore appear at first sight as though the best position would be on the top of a hill. This is not so, however, unless the house is protected from the winds by a belt of trees. Low-lying districts should be avoided in all cases if possible, as also should any hollows or places lower than the surrounding land. They are apt to be damp and cold. The banks of rivers, unless many feet above the highest level of the stream, should also be avoided, owing to the risk of floods and dampness.

Effect of Contours. The side of a hill is often selected as the site of a house, on the ground that the slope facilitates the drainage. It is never wise to build a house close in to a hill, such a site being damp and the house being liable to damage by the rush of heavy rains. A spur or projection from the side of a hill affords a good site and is not open to the objections just stated. While, generally speaking, sloping land affords, with the reservations just made, a good site, it is necessary to point out that one must consider also the aspect of the slope. Thus a slope facing south is infinitely to

be preferred to one facing north. Of course a house should not be too exposed to the glare of the sun.

Ground Water, Ground Moisture and Ground Air. Below the surface of the ground, at very varying depths, is a large sheet of water, termed the ground water. In some places its surface is only a foot or so below the ground, while in others it may be as much as hundreds of feet down. The depth of this ground water can be noted approximately by inspecting the water level of any wells in the neighbourhood, and the same method of inspection will disclose the fact that the level of the ground water fluctuates, rising or falling with the presence or absence of heavy rainfall. As the water rises, it forces up through the ground the air previously filling the pores of the soil above it, known as ground air, and takes the place of such air. On falling again, the interstices of the soil are left charged with moisture, termed ground moisture. Ground moisture is also due to the ground water rising by capillary attraction, or being soaked up by the soil and to the evaporation of the water.

It will be seen that if the level of the ground water is near the surface, the site will be damp; therefore one should not adopt a site, if avoidable, in which the highest level of the ground water is less than 10 feet below the surface. Both ground air and ground water are constantly moving and therefore require careful consideration. If one house be built at a lower level than another, on a hill-side, for example, there is a risk of soil pollution, the underground water being polluted in its course by leaky drains, cesspools and such things. The air forced upwards out of the soil may also be polluted from the same causes. Every care must be taken to see that the subsoil is free from pollution, since not only must the house itself be protected from the possibility of danger to health (which can be accomplished by means of an impervious layer over its site), but also the ground immediately adjoining the house.

Should the level of the ground water be rather high, the site may be greatly improved in value by the drainage of its subsoil.

Porosity of Soil. Let us next consider the situation of the house with regard to soil. One may divide this into surface soil and subsoil. The former is of shallow depth, generally formed by the decayed upper surface of the rocks below, mixed with the remains of animal and vegetable matter and often a quantity of alluvial deposit brought to it by running water. This surface soil is generally very absorbent, being disintegrated by worms, ants and other things, and so readily letting air down to the subsoil. The subsoil should be of a porous nature. One may put the principal

soils in the following order of preference from a hygienic point of view: gravel, sand, limestone, sandstone, chalk, loam and clay. It is of very great importance that there should be a fairly thick stratum of a porous material before an impermeable layer is reached, otherwise the subsoil will act as a sponge, soaking up and largely retaining the ground water and thus making the site a damp one. Trial holes or borings should be made to determine this point in any important case.

"Made" Soil. Sites of former gravel pits, clay workings and such features often become tips for house refuse and miscellaneous rubbish of all sorts, forming what is known as "made" soil. Made soils are very undesirable from a building point of view, being highly charged with organic matter and other impurities. After long exposure to the sun and air they become considerably purified, but they should not, in any case, be built upon for at least ten years after the land has ceased to be a rubbish tip, as it still remains an undesirable soil and may give rise to unequal settlement of foundations. Alluvial soils, and arable land, should also be avoided as good building sites if other land is available, so also should land which has been reclaimed at the mouth of a river.

Open Space Round Buildings. The greater the amount of open space around a building the healthier will it be. In the open country there is generally no difficulty on this point. In the towns, where land is more valuable, developers of land have, in the past, shown no great generosity in forming wide roads and laying them out on lines beneficial to the community at large. Local authorities are empowered, by the Public Health Acts or by various local Acts, to make by-laws regulating, among many other things, the width of new streets. The Ministry of Health —and its predecessor, the Local Government Board—have issued a code of Model By-Laws, which have been revised from time to time, and which now recommend a minimum width of 36 feet for new streets, except when these are of short length and small importance and the building line is set well back from the street. It is, however, open to any local authority to make by-laws (subject to official confirmation) prescribing a greater width than 36 feet as a minimum, and many authorities have done so. The County of London does not come within the purview of these Acts in regard to building and sanitary matters, and the minimum width of new streets here is covered by the London Building Act, which lays down a minimum of 40 feet. An open space is also required at the rear of every dwelling-house, both outside and in the County of London.

Planning schemes under the Town and Country Planning Acts usually permit streets to be of less width than required by the by-laws, if they are not likely to carry through traffic, are of short length and are to be flanked by dwelling-houses only; there will, however, be restrictions on the building lines in such schemes, and the houses will be kept well back from these narrow streets. It will be obvious that a narrow road, with the houses set well back, will be better, from a health point of view, than a wider road with the houses close up to it.

Planning schemes will also provide for the separation of industrial premises from dwellings, will limit the number of buildings per acre, and the proportion of each plot which can be built upon, so ensuring adequate air space and greater amenity.

Best Types of House. It will have been seen from the foregoing that some types of house are better than others; thus, a detached house is the best, since one can get fresh air and light on all four sides of it; a semi-detached house can be placed second in order of preference, air and light being obtainable on three sides. A terrace house is not so good since air and light are obtainable only at front and back. With good planning, however, a through current of air can be ensured. Economic considerations—the necessity of saving in cost of brickwork, roof timbers, etc.—often make it necessary to build in terraces or rows. Town Planning schemes usually limit the number of houses which may be built in one block and prescribe a minimum space between blocks.

Blocks of flats are sometimes designed so that they have a frontage on one side only of the building, so that there is no possibility of getting a through current of air. This is becoming rarer.

Back-to-back houses were once very prevalent in industrial districts, especially in the north of England, but the erection of this very unhealthy type of dwelling has long since been prohibited and older blocks of this type have already been or are gradually being cleared and replaced with more satisfactory accommodation.

The overcrowding of houses is, of course, a serious danger to health. The Housing Act, 1936, gives to Local Authorities power to take steps to reduce overcrowding where it exists and to demolish and re-develop insanitary areas, but it is necessary at the same time to provide new housing accommodation in convenient situations for displaced persons, so that progress in this respect cannot be very rapid.

CHAPTER III

The Building—Its Planning and Construction, Prevention of Dampness, Etc.

Effect of Good Planning in Sanitation. Given a site of sufficient area, it should be possible to design a house in a manner free from any hygienic or sanitary objections. There are certain broad principles to be kept in mind in preparing such a design. The rooms containing sanitary fittings should be grouped together, floor by floor, in order to simplify the drainage of the house by collecting its waste pipes at one side as much as possible. If this point is kept in mind a far better system of drainage will be possible than would otherwise be the case, as well as a more economical system. Rooms containing sanitary fittings should be isolated from the other rooms. In the case of a detached house it may be possible to group the sanitary apartments into a small wing and to isolate them, on each floor, by means of a small lobby, well lighted and ventilated, so as to prevent any possibility of smell finding its way into the main building. In a semi-detached or terrace house considerations of space usually prevent the formation of a separate sanitary wing, but the principle of isolation by lobbies should be carried out when possible.

The staircase of a large house should be fairly central and arranged so as to form a means of ventilation to the house as a whole. This point will be more fully dealt with later under the heading of ventilation.

The rooms should be of good size and fairly lofty, well lighted and ventilated and have at least one outside wall.

Access to Light and Air. Windows should be of good size (most local by-laws fix one-tenth of the floor area of living-rooms as a minimum, of which at least one-half should be openable). They should not be all in one corner, or at the end of a wall, but more nearly in the middle of one side of the room. They are also of the greatest efficiency when they extend nearly up to the ceiling, since then the room will get a maximum of light, and be more efficiently ventilated.

The building should be so planned that the natural light of any room is not prejudiced by extensive projecting "back additions" or wings and, like the rooms, all lobbies and passages should

have windows or overhead lights, communicating directly with the outside air. The question of natural and artificial lighting will be dealt with more fully later on.

Choice of Aspect. The placing of the building on the site is a matter of some importance, since certain rooms should have certain aspects.

Thus a living room, especially a dining-room, should preferably face south-east, to get the morning sun. A kitchen may well face north-east, when a little sun may be obtained before the hottest part of the day, though there is something in favour of the kitchen facing the garden and having a bright sunny aspect in the smaller type of house, where the housewife herself may have to spend a good deal of the day in the kitchen. The north side of the house is best for larders, etc., as this will be the coolest side. Rooms containing sanitary fittings should be placed so that the waste and other pipes are not exposed to cold winter winds, which might cause the water in them to freeze.

The principal bedrooms should preferably have an easterly or south-easterly aspect, to get the morning sun.

It will be obvious that the planning of a house cannot be rigidly standardised, owing to the exigencies of site and individual requirements as to accommodation, but the foregoing principles should be followed so far as practicable.

Site Drainage. Let us next consider the construction of the house, so far as it comes under the heading of sanitation. It has been pointed out that it should be put on a dry, porous soil and subsoil. It may be that this is impossible. In such case the subsoil should be improved by drainage.

This is another part of the subject on which architectural students would be wise to study the British Standard Code of Practice —that on Site Drainage.

A great deal can be done to lessen the evils due to ground water. If the house is not a very large one, the best plan is to lay subsoil drains around the foundations of the outside walls, falling to one corner of the building. These drains should be of unglazed pipes, without sockets, laid with butt joints (i.e. just end to end) and covered over to a depth of about 1 foot with broken stone, the remainder of the trench being filled in with ordinary earth. These are sometimes known as "French Drains". If laid round the building in this way, the drains of two sides of the building will fall in one direction and those on the two other sides in an opposite direction, the two sets of drains meeting at a point from which they are contained onwards as one drain. There can be no hard-and-

fast rule for the size of the drains, but those around the building can in most cases be 3 inches in diameter, continuing onwards from the point of junction with a diameter of 3 or 4 inches.

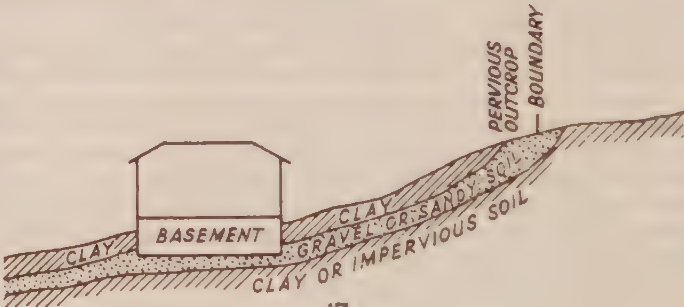
If the soil is very wet, or the building of considerable size, subsoil drains are frequently formed *under* the site of the building, but drains of any kind should not be put under a building if it can be avoided. In such a case a main drain of, say, 3 or 4 inches diameter can be laid diagonally across the site of the building, with branch drains of 2 inches diameter leading to it, laid herring-bone fashion on plan, at a distance of about 6 or 8 feet apart. It may be desirable to lay a subsoil drain around the building in addition. The subsoil drains should in all cases be below the level of the foundations of the walls.

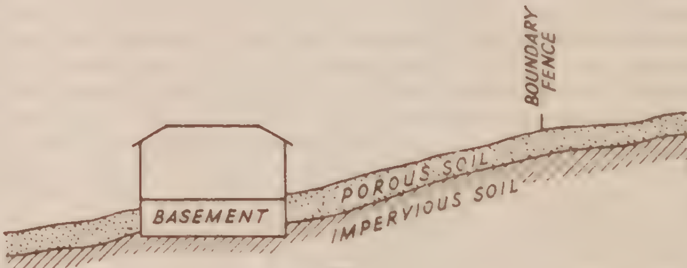
Whichever of these two methods may be adopted, the drains should be contained, from the point at which they are collected together, to a ditch or other watercourse if there is one on the property. Should there be no natural outfall of this kind, the main drain can discharge into the ordinary system of foul drainage provided that it is cut off, or intercepted, by a trap at the point of junction, in order to prevent the foul drains being ventilated into the soil through the subsoil drains. The trap may be a "reverse-acting" intercepting trap similar to the one which will be referred to later in the chapter on "house drainage", or can be a trapped gully with access arm placed in a brick chamber covered with a grating as Fig. 4a. Should there be a separate system of rain-water drains, the subsoil drains can be connected directly to it, without the intervention of the trap.

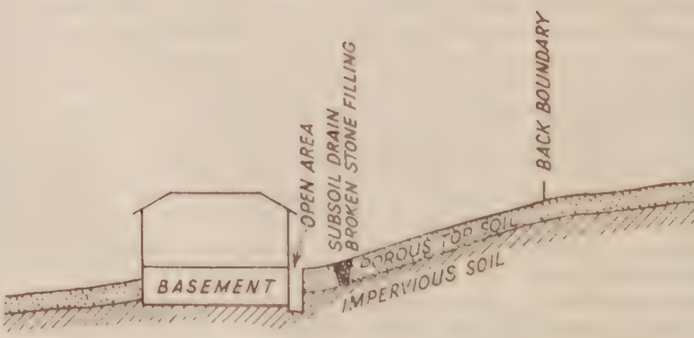
In these subsoil drains, the subsoil water percolates slowly through the soil and broken stone towards the open joints of the unglazed, butt-jointed pipe and then flows off more rapidly along the line of pipes to whatever outfall is provided, leaving the site very much drier than it otherwise would be.

It has already been pointed out that houses should not be built close to a hill-side. It is sometimes done, however, and in such a case the subsoil drainage requires very careful consideration. Trial holes should be sunk at various points around the site of the house, and the water level and nature of the subsoil carefully observed, the former being noted at various times owing to its fluctuation in the wet and dry periods.

Assume, for example, a case like that shown in Fig. 17, in which the basement of a house cuts through a bed of sand or gravel lying between an upper and lower stratum of clay. The bed of gravel is shown coming to the surface, or outcropping as it is termed,


PERVIOUS
OUTCROP
BOUNDARY
CLAY
BASEMENT
CLAY
GRAVEL OR SANDY SOIL
CLAY OR IMPERVIOUS SOIL
17


BOUNDARY
FENCE
BASEMENT
POROUS SOIL
IMPERVIOUS SOIL
18


OPEN AREA
SUBSOIL DRAIN
BROKEN STONE FILLING
BACK BOUNDARY
BASEMENT
POROUS TOP SOIL
IMPERVIOUS SOIL
19

some distance up the hill behind the house. In time of heavy rainfall there would be a stream of underground water passing through the porous stratum of gravel or sand and washing round the outside of the basement. The rain falling on the land between the outcrop and the house would not soak into the clay, but would pass on to the walls of the house. The walls might be protected by a layer of asphalt, but the interception of the water would be much better. Again, assume that the circumstances are as shown in Fig. 18, in which a bed of gravel or sand lies over a subsoil of clay. Here, also, there would be difficulty. The best method of dealing with either of these cases would be (1) to form an open area around the walls affected, carrying it down below the level of the basement floor and paving it, forming a gutter at the toe of the bank, with proper falls to gullies, in order to carry the water off, and (2) to form, also, a deep subsoil drain some distance back from the house and carried down to a depth sufficient to intercept the water from flowing or percolating to the foundations of the walls, as shown in Fig. 19, the trench being filled in with broken stone. The dip of the strata around the house would have to be carefully noted, so that the water might be intercepted properly. Thus, assume Fig. 20 to be a block plan of the site, showing the building, the arrowheads showing the dip of the strata. The subsoil drain would be given a slight fall from A to B and from the latter point it could be gradually brought out to the surface at some convenient point, or carried away to the nearest natural outfall, according to the use to which the surrounding land is put. Figs. 19 and 20 are not drawn to scale, the size of the drains being exaggerated for the sake of clearness.

As has been pointed out, it may or may not be necessary to drain the subsoil of a building, but whether it be necessary or not, there are many other causes of dampness which it is necessary to guard against.

General Causes of Dampness. The principal causes of dampness are the following: (1) moisture rising from the ground; (2) rain beating on the faces of the walls; (3) rain soaking downwards through the walls; (4) waste pipes fixed close to the walls and becoming defective; (5) defective roofs and gutters, and (6) defective fittings or burst pipes.

Prevention is always better than cure, and the means of preventing dampness arising from each of these causes will therefore be dealt with fully.

Ground Moisture. Air, as it becomes warm, tends to rise; therefore there will always be an upward tendency on the part of the

air in a building, since even though there be no warming of the air by heating or artificial lighting, yet it will be warmed and rendered lighter by mere contact with the occupants. Assume a house to be occupied, with all the external doors and lower windows closed; the air will be tending to rise and must be replaced from somewhere, or, if not replaced, will in time make the house very unhealthy. The house therefore tends to act as a sort of suction pump, and would draw air out of the soil—air possibly charged with organic impurities and moisture—if means were not taken to prevent it. It is therefore necessary to put a layer of cement concrete over the whole site of the building, of a thickness of not less than 6 inches, which effectively prevents the mischief, if properly done; if badly done, moisture and air will find their way through. Alternatives to a 6-inch layer of concrete are a 4-inch layer on a bed of clinker or broken brick.

Sub-floor Ventilation. As a sort of second line of defence, if an ordinary joist floor is used (that is, other than wood block floor), a clear air space should be left between the top of the concrete and the underside of the floor timbers. This space should be thoroughly ventilated by means of perforated air bricks or gratings, in order to protect the floor timbers from the possibility of dry rot. Where solid floors are constructed adjacent to hollow floors, it is essential to continue the ventilation path via ducts or pipes through the solid floor. This air space is of great value as a reserve precaution against the rise of ground air, though it is generally regarded only as a provision for the security of the timbers. There should be plenty of air bricks or gratings in the outer walls, and they should be carefully placed so as to ensure a through current of air, but this should not be overdone so as to cause discomfort to the occupants by cold draughts emerging at skirtings, etc. There are often too few of them. Care should be taken that they do not get obstructed by the formation of garden beds or rockeries in front of them. It is usual, in forming a ground floor where there are wooden joists, to make the joists of less depth than those of upper floors and to give them a proportionately shorter span. Accordingly, what are termed sleeper walls are provided to give intermediate support to the joists.

These walls, which are usually only a foot to 18 inches high, need not be more than a half-brick thick and should be built "honeycombed". This provides for the free circulation of air under the floor.

The wall rests on the concrete and carries a continuous wooden "plate", usually about 3 inches by 2 inches, on which the joists rest.

Damp-proof Courses. Notwithstanding the concrete over the site, and a thicker bed of concrete under the bases of all walls except sleeper walls, moisture will rise into the walls by capillary attraction from contact with the soil. This must be prevented by the use of a horizontal damp-proof course placed in all walls (including sleeper walls) not less than 6 inches above ground level and below the floor timbers, if these rest upon the walls.

The choice of solid floors at ground level rather than wood joist floors will be discussed at a later stage.

A damp-proof course should be durable, non-absorbent, obtainable in thin sheets, somewhat pliable (so that it may not be broken by uneven settlement of the building) and not so soft as to make it squeeze out under the weight of the super-structure.

A common form consists of two courses of slates, set in cement mortar and laid so as to break joint—that is, so that no two joints come over one another. This was a favourite form for small houses and was in most respects excellent, but has very largely been dropped in favour of a heavy bituminous d.p.c. on the score of economy in material and labour.

Sheet-lead and copper are also used and possess the virtue of being thin, pliable, easily laid and having few joints. They are to be preferred for use in parapet walls and chimney stacks. Lead is, however, relatively expensive, and is liable to chemical action when in contact with cement; the damage due to this can be avoided by placing the lead between two layers of bitumen. The lead can be comparatively thin and the combination with the felt makes this an ideal form of d.p.c.

Asphalt, laid in two layers, is pliable and jointless, but care has to be taken to secure a material which will not soften too much in hot weather. It needs careful laying by specialists in this kind of work and is therefore suitable only for large jobs.

Two courses of blue bricks form a favourite damp-proof course in districts in which these are cheap. The bricks themselves are non-absorbent, but the weakness of this method is the large number of joints, which should be made of cement mortar to which a waterproofing powder or solution has been added. The vertical joints are generally left open.

The Knapen System. A system now fairly well known in this country is the "Knapen" method of remedying or preventing dampness. It is the invention of a Belgian engineer and has been applied to many important buildings in France and Belgium.

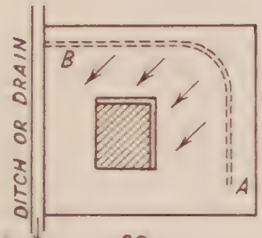
The system is quite simple, based on natural laws, and independent of any mechanical aid. It consists of inserting in the

wall small tubes made of a specially porous clay. These tubes incline upwards from the face of the wall to the middle of its thickness, and the lower or outlet ends are protected by small triangular gratings. When the moisture soaks through to the interior of the tube, it is absorbed by the dry air within, and the temperature of the air being reduced by the moisture—and its density thereby increased—it follows the law of gravity and sinks to the invert of the tube. The moisture-laden air continues to fall and flows down the invert until it escapes through the grating. A further supply of dry air enters through the upper half of the tube to take its place. This air, being less dense than that in the lower half, naturally rises, and on reaching the higher end of the tube it in turn becomes saturated and falls to the invert, escaping as before. The tubes are of special section in order to give maximum efficiency, and their distance apart requires to be carefully calculated so that the area of activity of each slightly overlaps that of the next.

The system can be used as a substitute for damp courses, and it can also be applied throughout an old wall built without a damp-proof course, as a remedy for dampness.

Where the house has no basement the construction around the base of the wall might be as shown in Fig. 22, in which the double line shows the damp course and A.B. the air ducts, which are openings in the wall 9 inches wide and 6 inches high, spaced at about 10 feet centres, and protected against entry of vermin by terra-cotta or cast-iron air bricks or gratings. It will be noticed that the air ducts are placed in the most efficient place for ventilating the floor timbers and that they are high enough above the original ground to make it unlikely they will be choked by added soil, leaves, etc. A 6-inch layer of concrete is shown well below the floor timbers.

Treatment of Basements. Basements to dwellings should be avoided if possible, but in a house built with one, the level of the floor of which is considerably below the level of the soil, efficient ventilation of the floor becomes difficult and it is generally better to avoid a timber floor altogether. The floor can consist of concrete covered with tiles or granolithic paving. Fig. 23 shows a method of construction, whereby the soil is kept from contact with the wall above the damp course. In the method illustrated an open area is formed outside the walls, wide enough to walk in, paved with concrete rendered in cement mortar and laid with falls to gullies spaced at suitable intervals. The earth is kept up by a retaining wall. No air duct is shown, as none is required, there



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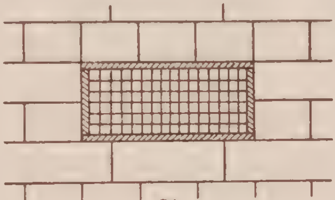

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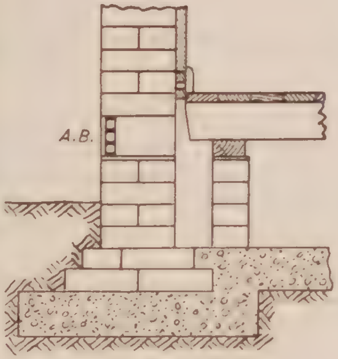

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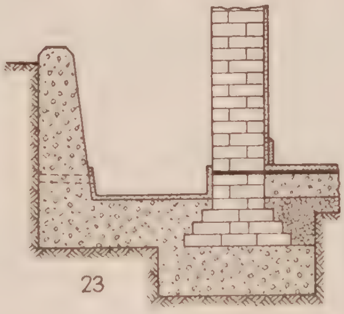

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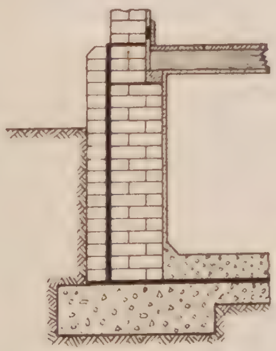

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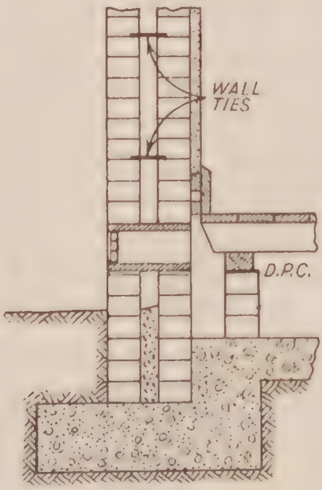

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being no timber in the floor construction and a waterproof membrane of asphalt is placed between the concrete and the finished surface of "in situ" flooring.

Vertical Damp-proof Courses. A method by which an area is avoided is shown in Fig. 24, a vertical damp course of two layers of asphalt being placed on the outside of the main wall, joining up with two horizontal damp courses, one in its usual position above ground and the other below the basement floor; this latter course is continued all over the site in between two layers of concrete if the site is a very wet one. To avoid having to make a wide and deep excavation outside the house, for the purpose of laying the vertical damp course below ground level, it is usual to build up an additional half-brick wall, as shown, before the main wall is built. The asphalt can then be laid from the inside against this wall, after which the main wall can be erected immediately against the asphalt.

Rain Penetration of Walls. In normal years rain will not penetrate through brick walls of a thickness of 13½ inches or more if good quality bricks and mortar are used and the work is well put together. At times water may penetrate some way into the wall, but this will become evaporated when a spell of fine weather follows.

Very heavy rain, driven by the wind against a wall, may penetrate a wall 9 inches thick, composed of good bricks in cement mortar, but is not likely to do so through a 13½-inch wall.

When for economy's sake the wall thickness is limited to 9 inches and the position of the building is somewhat exposed, or, if the bricks to be used are not of very good quality, some form of protection should be provided against damp.

Rendering. One method, as good as any, is to render the outside of the walls with two coats of cement mortar, the under coat preferably having a waterproofing liquid or powder mixed with it. The objections to the method are its appearance and the fact that fine cracks may occur, especially if it is laid in hot weather, in which case water is likely to enter them and the rendering prevents its evaporation.

"Rough cast" and "pebble dash" are merely variations of the above and are much used for small houses, for which their appearance is more pleasing than that of a plain surface.

Another method is to hang tiles or slates on the outside of the walls. These form an excellent protection but the method is costly in most localities.

Cavity Walls. The normal method in good modern practice

is to build the wall in two thicknesses with a cavity 2 inches wide between. Such walls are known as "cavity walls". The outside part is invariably $4\frac{1}{2}$ inches thick, the inside part usually $4\frac{1}{2}$ inches, but occasionally 9 inches or more. Fig. 25 shows the construction and it will be noticed that the cavity extends down to ground level, the damp course not extending across the cavity, which should not be ventilated.

Figs. 22 and 25 show a slate boxing built round the ventilating opening for the efficient ventilation of a wood floor. As an alternative to the slate box, an earthenware pipe may be inserted, sloping gently to the exterior face of the outer wall.

To stiffen the wall, its two parts are held together by wall ties of galvanised iron wire or shaped ties of galvanised iron, copper or copper alloy so formed as to prevent water from passing from the outer part of the wall to the inner leaf.

Rain Penetrating from Roof. If a house is roofed with slates or tiles and has overhanging eaves and the roof is kept in perfect condition, the only possibility of this happening is by means of the chimney stacks. The stacks should have a damp course immediately above the roof and the junctions of the stacks with the roof covering must be protected by flashings, as will be described later, under the heading of "Roofs and Gutters". Sometimes, however, certain of the walls extend above the roof, these being called "parapet walls"; means must then be taken to prevent rain soaking downwards.

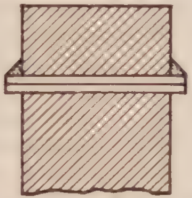
An attempt to meet the case is made by forming the top course of non-absorbent bricks set and bedded in cement. Less unsightly, but also apt to be less efficient, is the formation of the top course of ordinary bricks set and bedded in cement. Other methods consist of (*a*) tile creasing with a course of bricks above as in Fig. 26; (*b*) a course of drip tiles as in Fig. 27, (*c*) a proper coping of stone or terra-cotta, and (*d*) a metal through-wall flashing or covering. Tile creasing is used, as a rule, under a course of bricks set in cement mortar edgewise. The creasing consists of two courses of roofing tiles, laid breaking joint, and bedded and jointed in cement mortar. Above the tiles, where they project, it is usual to put a triangular fillet of cement mortar to throw the water off. Drip tiles, as shown in Fig. 27, are laid in one course only, being set in cement mortar and usually having the course of bricks above, as in tile creasing. The downward slope of the projecting part of the tile causes the water to drip clear of the wall. All the above methods are open to the objection that any shrinkage of the joints lets the water in.

The best method of dealing with this case, therefore, is to use a proper coping, shaped at the top so as to throw the water off and projecting on each side as shown in Figs. 31 and 34. The upper side of the coping is sloped or curved, to throw off the water and the underside has its edges projecting downwards, as shown in Fig. 27, or has grooves or "throats" as shown in Fig. 31. In either case the object is the same—to make the water fall off the coping clear of the faces of the wall. Other projections from the building, such as window sills and string courses, should be throated in the same manner as the coping of Fig. 31. The relevant British Code of Practice advises two damp-proof courses, one at flashing level and one below the parapet gutter, but above the principal timbers, with the insertion of a short piece of cavity wall between them to cut off completely the woodwork from the outer face of the wall, as shown in Fig. 31.

Parapet roofs are rather more liable to cause dampness inside the building than the ordinary eaves roof in the event of the gutter becoming defective.

Defective Waste and Rainwater Pipes. This cause of dampness arises chiefly from overflowing eaves gutters, through their outlets being choked with leaves or their being given insufficient fall towards the outlets, and from choked rainwater pipes; these sometimes become choked by ice, rust or other things at their lower ends. They are usually jointed with red-lead putty, in which case, if they are choked and become full of water, this will overflow at the top. Sometimes no jointing material is used, in which case they will, if choked, leak at the bottom joints. In either case, a damp patch is caused on the wall which may spoil the interior decorations. Provided the rainwater pipe is not used also to convey waste-water and is fixed with spacing-pieces to keep the pipe 1½ or 2 inches from the wall, this is unlikely to happen and the jointing material may be safely omitted. This also permits painting all round the pipe when redecorating. If, however, the "down pipe" carries waste-water as well as rainwater, it must be treated like a waste pipe and properly jointed with red lead and chopped hemp, or, if the socket is stout enough to stand caulking, with a caulked lead joint. Usually, however, rainwater and waste-pipes are of too light a weight to stand caulking.

Slope of Roofs of Different Materials. The more absorbent the roof covering, the smaller the pieces in which the roof covering is used, and the more irregular their shape, the steeper should be the slope of the roof. Thus tiles are smaller than slates, and owing to slight warpings in the process of burning, they do not lie so



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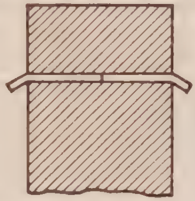

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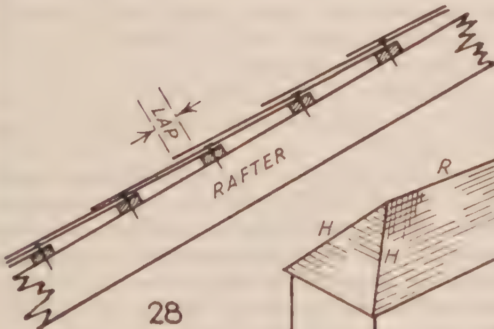

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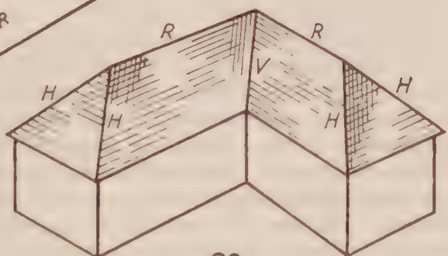

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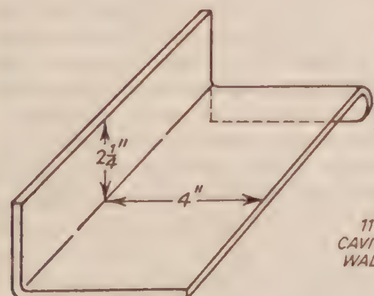

LEAD SOAKER OR LEAD SLATE WHICH CAN BE BENT OR ADAPTED TO VARIOUS SHAPES AND POSITIONS

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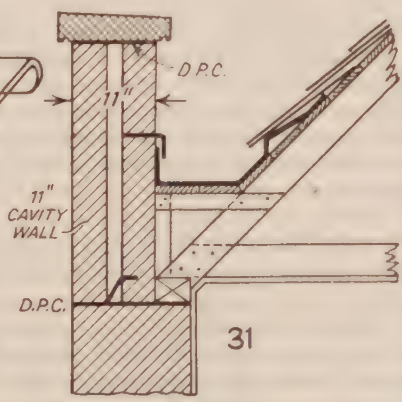

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closely together as slates. Consequently the pitch or slope of a tiled roof is made usually about 45° and that of a slated roof about 30°. On the other hand, materials which can be used in large pieces and which are capable of a fairly close joint can be laid to a very slight fall. Milled lead, zinc and copper are all used, are quite non-absorbent and are laid in sheets of considerable size; they can therefore be laid with as small a fall as 1½ inches in 10 feet, with (in addition) vertical drips of about 2 inches at each end joint, which, however, are often omitted in the case of copper. Asphalt and other bituminous coverings are non-absorbent and practically jointless, so that they can have as little fall as 1½ inches in 10 feet.

The slope of a roof is dependent on other points in addition to the foregoing. The architectural style of the building may call for a particular sort of roof. The liability to falls of snow is another point to be considered. In countries like Norway one finds roofs of very high pitch, whereas in Southern Europe one generally finds the flat roof.

Sarking Felt. Slated and tiled roofs can be rendered more secure against the elements by putting boarding and inodorous bituminous felt under the battens. The greater thickness of tiles, and the fact that they are not such good conductors of heat, make tiles the better of the two materials from the point of view of keeping a building warm in winter and cool in summer, this point being of some importance where rooms are formed in the roof.

Slates. The best-known slates are those from Wales, particularly those from the Penrhyn and other quarries in the neighbourhood of Bangor. Other good varieties are obtained in the Festiniog and Portmadoc districts of Wales and in Westmorland and Cumberland. In Scotland perhaps the best known is the Easdale, and in Ireland the Valencia slate. Delabole, in Cornwall, furnishes a thick slate often used on account of its appearance.

Many slates are imported, but these are often unsatisfactory.

Slates are secured by means of copper, zinc or composition nails, iron nails being unsuitable because they are liable to corrode. They can be nailed near the head of the slate or near the centre, the former being often preferred, as every nail is covered by two slates. On the other hand, the leverage on the heads of the nails is greater and the expense is increased; consequently the centre nailing is more usual. The size most generally used is the Countess, which is 20 inches by 10, and laid to a lap of 3 inches. The tail, or lower edge, of each course overlaps the head, or upper edge, of the course next but one below it, to an extent termed the lap as shown in Fig. 28, the distance from the tail of one course to

the tail of the next course below being termed the gauge or margin. If the slating is nailed at the head, the lap is the distance from the nail hole in any course to the tail of the course next but one above it. At the top and bottom edges of the roof, double courses of slates must be put, in order to prevent water passing through the joints between the adjacent edges of the slates in the upper course at the bottom edge and of the under course at the top edge of the slope.

Ridges. The ridge or summit, formed by two adjacent and opposite slopes, is made watertight by several methods. One is to use ridge tiles moulded to the shape of a half round or an inverted **V** and bedded on mortar. Another method is that of forming the ridge of lead or copper. In this case a wooden roll may be put on top of the wooden ridge and sheet-lead or copper dressed over from side to side, the edges of the ridging being secured with lead or copper tacks.

Hips and Valleys. Slopes intersect at other points than the ridge, forming hips and valleys, the former being the external angles and the latter internal. Thus, in Fig. 29, the ridges are marked **R**, the hips **H** and the valley **V**. The hips are usually formed in a slated roof, in the same manner as the ridge. In the case of the valley, a lead or copper gutter is formed in the angle and under the slates, small fillets being fixed on the slopes of the roofs to lift the slates slightly out of the gutter thus formed so as to prevent capillary action.

Tiles. Tiles for roofing work are of many kinds, such as the plain tile, the pan tile (with a roll or wave in its width), the double roll tile (with two such waves) and many forms of interlocking tile. The best-known and ordinary form is, of course, the plain tile, $10\frac{1}{2}$ by $6\frac{1}{2}$ inches and about $\frac{1}{2}$ inch thick. Tiles are laid in a similar way to slates, each course having a lap over the next but one course below it, with double courses at top and bottom of the roof. Tiles may be fixed by hanging them on the battens by means of projecting nibs moulded on their under sides, every fourth or fifth course being nailed by means of copper, zinc or composition nails.

The ridges of tiled roofs are always finished with ridge tiles set in mortar, and hip and valley tiles, specially moulded, are generally used for hips and valleys.

Parapet Gutters. It is not within the province of this book to go very fully into the subject of general building construction, but the details of roof work, so far as they affect the prevention of damp, must be dealt with.

Tapering Gutters. A gutter behind a parapet may be of either tapering or parallel form on plan. Fig. 31 shows an example. All gutters must have a good fall, and a gutter, such as that shown, should have a fall of not less than about 2 inches in 10 feet. It is carried by bearers, fixed at varying heights, in order to give the fall, with the result that the gutter is of tapering form on plan. The least width should be 9 inches. It will be seen that the bearers carry gutter boards and that a small triangular fillet prevents the water from getting up under the slates. The lead or copper is shown by means of a thick line and is in two pieces, (1) the main gutter, and (2) a flashing fixed into the joints of the brickwork or into a groove formed in stonework. This flashing should lap well over the vertical side of the gutter but should not be carried nearer than about 2 inches to the bed of the gutter. The transverse joints should be formed by means of steps or drips, details of which will be found later under the heading of flats. These should occur at intervals of not more than 10 feet. Where a long gutter falls for half its length in one direction and half in another, the joint at the summit should be formed by means of a roll, details of which will also be found later. The flashing should be secured by either cast-lead wedges, or strips of copper $\frac{3}{4}$ inch wide, folded and hammered into wedges, or by small round pebbles. Iron wall hooks, or oak wedges, are sometimes used but are open to objection; the former on the ground that they rust away and become loose, and the latter on the ground that they shrink.

Snow boards or grids should be provided to all such gutters, so that the snow does not impede the flow of water more than necessary. These should be kept well up off the gutter.

Ventilation of Ends of Roof Timbers. Generally there is no lack of air around roof timbers but it does sometimes happen that there is a closed-in space where air circulation is restricted and where, with the least suspicion of damp in addition, dry rot might find a foothold. Fig. 34 at AB shows an air-brick or grating with a narrow space left between the end of the tie-beam and the brickwork to allow free circulation of air.

The outlets from these parapet gutters should be provided with wire guards to prevent their becoming obstructed by leaves or birds' nests.

Gutters and flashings are often formed of zinc, but it is inferior to lead or copper and should be avoided wherever possible. The general arrangement, if copper or zinc be used in the two cases just illustrated, is very similar, but the flashings should be

"beaded" at the lower edge to stiffen them. An example of a zinc flashing is given later under the heading of flat roofs.

Flashings and Aprons. Where a wall or chimney cuts through a roof, a small gutter, very similar to that shown in Fig. 31, must be provided, the only difference being that the gutter behind the chimney would be smaller.

On the lower side of a feature an "apron" of sheet-lead, copper or zinc is provided, secured at its top edge in the same way as flashing and dressed over the slates or tiles as shown in Fig. 32. For a chimney the apron is generally in one piece, but for a long wall it should be of pieces not longer than about 10 feet, well lapped at the joints.

At the side abutments, a flashing should be used. In the case of brickwork that of the type known as "stepped". Fig. 33 shows an elevation of a stepped flashing against the side of a brick chimney stack. It consists of a piece of flashing cut so that its upper edge is in steps, to enable it to be wedged into the horizontal joints of the brickwork. The fronts of the steps are cut so that they slope backwards in order to prevent rain driving in between the flashing and the brickwork. If it were so cut that the fronts were vertical and in such a position that they could also be wedged into the vertical joints of the brickwork, the upper edge of the flashing would, it will be seen, be very irregular and unsightly. The lower end of the flashing is dressed round the corner over the apron, and the joint at the upper end is made, as shown, by dressing over the end of the gutter. The flashing to the gutter is also shown dressed round the corner to form a finish. In the case of copper welting or welding is carried out at the corners.

In the case of stonework, the upper edge is generally straight and parallel to the slope of the roof, being turned into a groove or raglet, cut in the stone and, of course, wedged.

The lower edge of the flashing is usually dressed over the slates or tiles as shown in Fig. 35, the flashing being shown by a thick line. A superior method of construction is that shown in Fig. 36. In this case the tilting fillet is fixed a little way from the chimney or wall (about 2 inches), and a small secret gutter is formed.

Soakers. An alternative method of dealing with such a case is to use what are termed soakers, with a flashing over them. Soakers are relatively small pieces of lead, copper or zinc, which may be bent to a right angle and built in with the slating as the roof is covered. An example is shown in Fig. 30. The soakers lap well over one another and either a stepped or raking flashing covers thin top edges. Another use for a soaker is to make a watertight

joint where a pipe or similar feature passes through the slates or tiles. A suitable opening can be cut for the pipe and the lead is dressed upwards against it, and made watertight. The outer edges of the soaker are then dressed over and under the slates exactly as if the soaker itself were a flexible slate.

Other Roofing Materials. Corrugated iron sheets are often used for roofing sheds or large temporary buildings. They should be of good quality and well galvanised or they will soon rust through. The sheets are well lapped on all sides and secured by galvanised screws and washers set in white lead. Such a covering should be given a slope of not less than 1 in 10. On the decay of any part of the coating, a galvanic action is set up which rapidly destroys the iron covering. It is therefore desirable that this should be painted six months after erection and every few years subsequently.

Corrugated asbestos cement sheets have largely superseded galvanised iron; they possess the merits of being non-corrodible and therefore more lasting; they do not need painting; they are less noisy in windy weather.

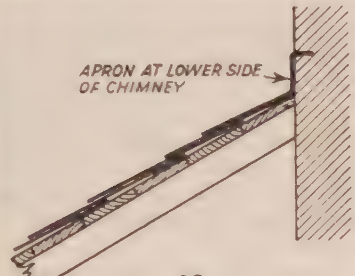
There is a B.S. Code of Practice in this material for those who need special details of the best methods of construction in it.

Thatch is a very good covering for country cottages, if the picturesque is required and if the roof has a steep pitch; gutters and down-pipes are not needed, the thatch being given a large overhang at the eaves to throw the rain clear of the walls below.

Flat Roofs. Flat roofs may have metallic or bituminous surfaces.

The metals in use for this purpose are lead, zinc and copper. Of these zinc is the cheapest, but is definitely much inferior to the other two in durability. Whichever is used, the sheets must not be too large, owing to the expansion and contraction which occur with changes of temperature. For lead flats, a width of from 2 feet 3 inches to 2 feet 9 inches and a length of 7 feet would be about normal size. The fall is in the direction of the length of the sheet and will be about 1½ inches in each sheet. The long edges of the sheets should be jointed by means of "rolls", whilst the cross joints are made by lapping the sheets in vertical "drips", not less than 2 inches high.

Figs. 37 and 38 show the roll formed in lead, the edge of one sheet being dressed half way round a wood roll about 2 inches × 2 inches or nearly to the top. This edge should be rasped away almost to a knife edge and tacked close so that the second sheet (shown in Fig. 38) can be dressed over as an overcloak to lie 1½ inches on the flat alongside the roll. The lead must be



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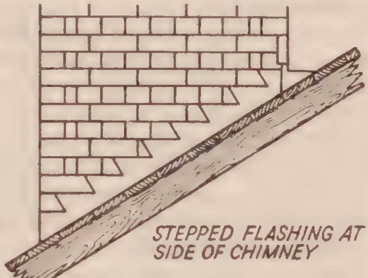

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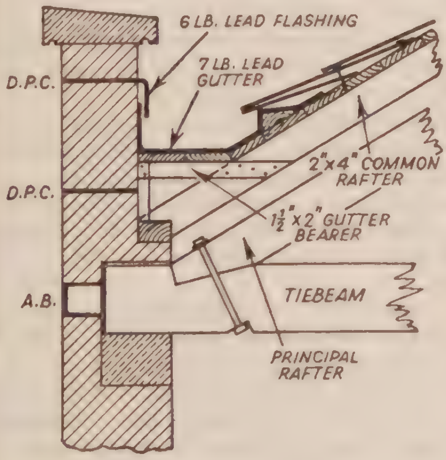

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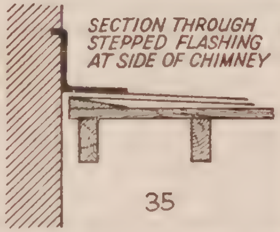

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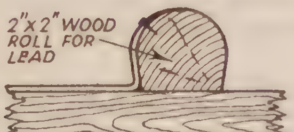


FIRST SHEET DRESSED WELL INTO ANGLE, EDGE TAPERED AND NAILED

37

SECOND SHEET DRESSED RIGHT OVER ROLL WITH 1½" EXTRA ON FLAT AS OVERCLOAK

38

tafted close in to the angles so that there shall be no fear of lifting by winter gales.

Fig. 39 shows a roll in a zinc flat. It will be seen that the shape differs considerably from that of a lead roll, owing to the fact that zinc is not soft enough to be readily dressed around a curved surface. The edges of the sheets are turned up against the side of the wood and are held down by clips, or tingles, which are strips about $1\frac{1}{2}$ inches wide, placed about 3 feet apart. The roll is then covered by a capping, which is secured to the tingles by clips soldered to its underside. The ends of the rolls are protected by shaped pieces soldered on.

Rolls can be formed in copper for roofs that are likely to carry pedestrian traffic as in Fig. 44, or by a triangular roll with only a single seam as in Fig. 51. Other roofs can be made by means of what is called a "standing seam". This is illustrated in Fig. 40. Double or single lock cross-welts are used for transverse joints, the former (shown in Fig. 44a) for flat and low-pitched roofs and the latter (Fig. 44b) on steep or vertical surfaces.

Figs. 41 and 42 show lead "drips". The lower sheet is let into a rebate or sinking on the edge of the upper boards at A, so as not to cause a ridge there, and the upper sheet laps over it, and extends along the lower flat, as shown in Fig. 41, or the member marked X may be retracted a little as in Fig. 42 with the lower sheet of lead dressed back so as to form an anti-capillary groove.

Fig. 43 shows a zinc drip. Instead of being turned into a rebate or sinking, as with lead, the top edge of the lower sheet is bent forward and the upper sheet is bent to form a roll or bend around it.

Where a metallic flat abuts against a wall the sheet is carried up the wall for a minimum of 6 inches and covered by a flashing, exactly similar to the flashing used at the side of a gutter; such a flashing is shown in Figs. 31 and 34. A flashing suitable for a zinc flat is shown in Fig. 45, the lower edge being beaded to check its tendency to curl outwards. This tendency is usually guarded against on copper flashings by means of a bead and a 2-inch wide copper cleat every 18 inches.

Bituminous Flats. Flat roofs are now more frequently constructed of concrete in combination with steel and, although these can be covered with copper, asphalt and built-up bituminous felt are the most likely to be used.

These materials are sanitary, damp-resisting, tough, durable, non-absorbent and slightly elastic, so that slight movement of the substructure does not crack them. Being to all intents and pur-

poses jointless no rolls or drips are needed. The chief objection to them is that, owing to their black colour, heat and cold are easily transmitted through them to the room below and painting with white or light-coloured paint does not seem to remedy this fault appreciably. It can, however, to a great extent be remedied by covering the surface with thin slabs of precast concrete or asbestos, bedded and jointed in sand and bitumen; this is especially desirable on roofs of asphalt, as this substance is liable to perish if exposed to the ultra-violet rays of direct sunshine.

Natural asphalt is laid in two layers on one or two layers of bituminous felt. The thickness of the asphalt should be ½ inch to ¾ inch.

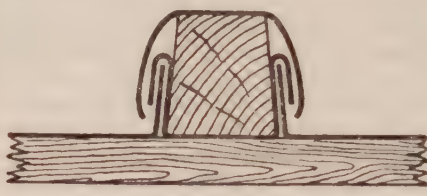
Where an asphalt flat abuts against a parapet (or other) wall, the asphalt should be carried up the wall for at least 6 inches, the top edge being secured by being let into a 1 inch × 1 inch chase cut in the wall and covered by a metal flashing as in Fig. 45 or the asphalt may be carried right through the wall to form a damp-proof course to prevent rain soaking into the exposed part of the parapet and from seeping downwards. The right-angled junction between the horizontal and vertical faces should be protected by a 2-inch fillet of asphalt laid as a separate operation. The surfaces concerned should be warmed and cleaned by the temporary application of hot mastic before the fillet is formed.

Fig. 46 shows a similar feature in bituminous felt on a timber sub-structure, suitable for the flat roof of smaller buildings or portions of buildings.

Eaves Gutters for Flat Roofs. Where asphalt flats are to discharge into an eaves gutter, a strip of lead or copper may be bedded between the two layers of asphalt and dressed down into the gutter as shown in Fig. 47.

The verge or edge, if there is no parapet wall, may be raised as in Fig. 48. The outlets from box gutters in asphalt flats are formed in various ways, but need special care, more so than with eaves gutters and cast iron fitments with gratings, and recesses to take the edge of the asphalt are perhaps the best as in Fig. 49.

Bituminous felt, which is felt soaked in hot bitumen, is a fairly satisfactory alternative to asphalt and is usually rather cheaper. Generally three layers of felt are used, each being laid in a brush coat of hot bitumen. Some hot bitumen is poured over the last layer, brushed even and either sanded or covered with fine gravel or tarmacadam; alternatively, it may be covered with concrete or asbestos slabs, which protect it from the action of sunlight and reduce the thermal conductivity of the roof.



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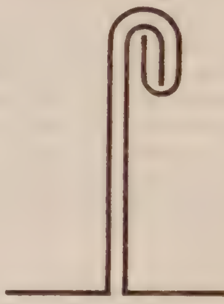

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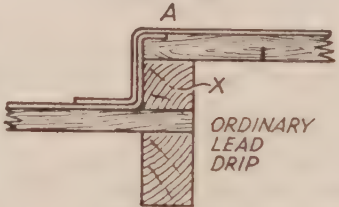

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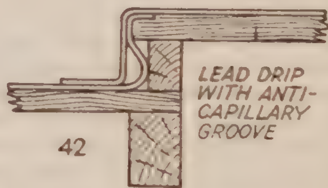

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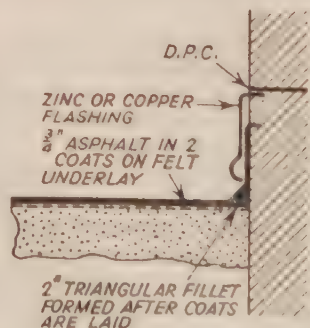

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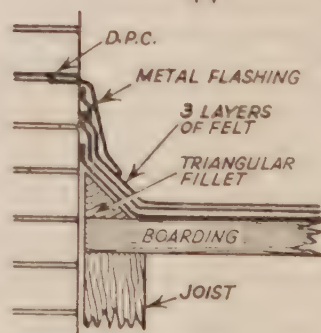

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Students intending to specialise in flat-roofed buildings to any extent should certainly study the British Codes of Practice in asphalt and other forms of flat roofing.

Defective Pipes and Fittings. These are an occasional cause of dampness, but one which is always avoidable. Well-designed and properly fixed fittings, together with pipes fixed against internal walls, need never be a cause of dampness. Where pipes are fixed against external walls, the danger of damage from frost is much greater, but there are many methods of protection in the way of casing them with non-conducting materials, such as hair felt, slag wool, and similar things.

Let us next consider the construction and equipment of the building from other standpoints of a sanitary or hygienic nature.

Partition Walls. If walls are plastered, the plaster should be carried down behind the skirting board to prevent the entrance of vermin. The old-fashioned lath and plaster partition with its timber posts or studs should not be used. It takes up more room than a partition of fire-resisting slabs and affords a refuge for vermin. There are many types of solid slab partition, made up of thin, strong slabs, readily finished with plaster on either face. They have, however, the drawback that they are apt readily to transmit sound. Hollow tile partitions are now much in use. They are terra-cotta or brick, with two or more cavities, across which are thin connecting webs. They are lighter, more fireproof and more soundproof than solid partitions of equal thickness. Their faces are either smooth or keyed to take plaster facings.

Wall Finishes. There should be as few surfaces as possible on which dust can collect. Elaborate mouldings, cornices, high-relief lincrusta or anaglypta should be avoided on this ground. In hospitals, where absolutely sanitary conditions are a *sine qua non*, internal angles are avoided entirely, all angles, including those between walls and floors, being rounded.

Walls should be plastered in order to give a smooth surface on which but little dust can collect. The wall surface can be finished with paint, distemper or paper. The first named is generally out of the question on account of condensation, but effectually prevents the absorption of impurities by the plaster. Washable distemper, having a dull surface, is pleasing in appearance and can be readily cleansed. Washable distemper is a thoroughly sanitary material, but common distemper is much inferior. If the surface is good and entirely free from damp penetration, plastic emulsion paint gives a pleasing and satisfactory surface. It may

not be so good in a kitchen or bathroom where condensation is to be expected.

Paper, unless it is of the variety known as "sanitary" wallpaper, has a rough surface which readily collects and retains dust. The appearance of sanitary wallpaper, with its slight glaze, prevents its extensive use. Whenever wallpaper is renewed, the old paper should be entirely removed from the walls, as it will have absorbed dirt and possibly not be free from germs, while behind it will be decomposed paste in most cases. The walls should be well washed down with water containing a disinfectant before repapering.

For such rooms as sculleries, bathrooms, and water-closets, a glazed surface is desirable for the walls. For sculleries, tiles or glazed bricks are the best, failing which the walls should be painted or varnished. For bathrooms, enamelled walls are good if tiling is objected to. A lining of enamelled zinc, forming imitation tiling, is quite sanitary. If expense prevents either of these alternatives, varnished paper may be used, but ordinary unvarnished paper is quite unsuitable. Non-absorbent wall surfaces have the drawback that they encourage the condensation of moisture, but their sanitary advantages outweigh this consideration.

W.C. Walls. For closets, it is a good plan to tile the walls, or, at any rate, to put a tiled dado, with enamelled walls. Here, again, if it is a matter of strict economy, paint, or varnished paper, may be allowed as a cheap substitute.

Where papers are used, the paste used to hang them is liable to ferment unless means are taken to prevent it. This can be done by the addition of a small quantity of alum or oil of cloves.

Cellar and Basement Floors. The best types of floor here are solid floors of concrete, covered with a waterproof membrane of asphalt and then finished quarry tiles, accotile flooring, granolithic paving or one of the coloured bituminous floorings which are now on the market. If the basement is part of the living quarters, the finish may be of hardwood strip or blocks set in a bitumen preparation such as Synthaprufe or Aquaseal.

Ground Floors. Modern houses are seldom built with basements and, if the site is fairly level, the ground floor can then be constructed as a solid floor, instead of its being carried on joists. The 6 inches of concrete which covers the site can form the base of this. The surface may consist of wood blocks about 1½ inches thickness or even as thin as ½ inch if economy is important and a suitable kind of hardwood is used. They should be laid on ⅛ inch of bitumen on the concrete after dipping them to half their depth in hot

tar, or of tongued and grooved wood boards nailed to creosoted fillets, secured by metal clips to the concrete. For sculleries, lavatories, etc., tiles, jointed in cement, or terrazzo paving, cork composition or other such non-porous surface, should be used instead of wood. For some public buildings a rubber floor, stuck to the concrete with an adhesive, may be preferred, but is rather costly for general use in dwelling-houses.

When the site of the house is quite level, but not otherwise, a solid ground floor will be cheaper than a joist floor, especially if account is taken of the fact that about two courses of brickwork are saved in the height of the house, by reason of the fact that the surface of the ground floor can be about 6 inches lower. This is because, in a joist floor, the joists and the wooden plates on which they rest must be above the damp-proof course, whereas in a solid floor all that is required is that the wood blocks or fillets must have their under-sides above the damp course. Quite obviously the solid floor is the more sanitary.

Solid floors may be wax polished or varnished and either of these methods of treatment will make them less porous.

For ordinary rooms, if a carpet is used, it should not entirely cover the floor, but leave a margin round the room. Fixed carpets do not provide a really sanitary floor covering. Easily removable rugs are much better, as they can be taken up and shaken daily. It is true that modern vacuum cleaners are very efficient, but with an all over carpet, it is difficult to get at the portions under heavy furniture of "almost" fixed type e.g. sideboards, bookcases, etc.

This, however, is really a matter of hygiene rather than sanitation and not really within the scope of this volume.

Ceilings. Lastly, a word or two with regard to ceilings. Panelled or painted ceilings are the best, being non-absorbent. If distemper is used it should be of high quality on plaster composed of clean sand and gypsum plaster or lime plaster or calcium sulphate plaster.

Ceiling papers are sometimes used to hide a poor plaster ceiling but a good washable distemper straight on to the plaster or a painted ceiling are to be preferred on sanitary grounds.

Some people like the appearance of a painted embossed paper like anaglypta. This, if well cemented to the ceiling and given two or three coats of paint to seal up all the pores, makes a good finish for those who like it.

CHAPTER IV

THE BUILDING—ITS VENTILATION

Necessity for Ventilation. The necessity for ventilation of dwellings and other buildings has always existed, though the means adopted and the degree of air change have naturally varied according to the purse, knowledge and ideas of refinement of the inhabitants. Perhaps the more primitive of our forebears needed less change of air in their dwellings, since the greater part of their life was spent outside, but even their mud huts had an opening in the roof to let the smoke out and the air in. Probably the two earliest official pronouncements in the way of ventilation were in the forms of proclamations by James I and Charles I respectively. Realising the difficulties of the circulation of air in narrow streets, with buildings having upper storeys which projected considerably beyond those below, James I, in 1619, ordered the walls of all new buildings to be carried straight up, while in 1631 Charles I, by proclamation, fixed the minimum heights of rooms and proportions of windows "for the benefit of ventilation".

Public Control of Ventilation. In recent times local authorities have been given considerable control over the erection of buildings in their districts. The Town and Country Planning Acts enable them to plan towns and control the development of private estates; among the objects in view are the restriction of the density of new houses, the separation of industries from dwellings and the provision of open spaces. The Housing Acts to a great extent ensure that new working-class houses shall be of adequate capacity and shall not become overcrowded.

Effect of By-laws. By means of by-laws the local authority can require reasonable air space in front of buildings and behind them; can specify a minimum height for habitable rooms (usually 8 feet); can require a minimum window area for such rooms (a very usual by-law requires this to be at least one-tenth of the floor area of the room, of which half must be made to open). Also, under the Model By-laws, every such room must have either a fireplace opening or a ventilator not less than 30 square inches in area.

It should be pointed out that local by-laws give the *minimum* that will satisfy the council, not of necessity the ideal conditions, and most people would look upon a room with windows only one-tenth the floor area as poorly lighted.

Unfortunately there is no certainty that the windows will ever be opened and that the ventilators will not be stopped up (a not unlikely happening if they are placed in such positions as to cause draughts or are made so large as to cool the air unduly).

On these accounts the local authority is quite unable to ensure that there will in fact be an adequate flow of air through rooms.

There are perhaps few subjects which are in a more unsatisfactory state than that of ventilation, or the removal and dilution of the products of respiration and combustion, though a large amount of experimental work has been done in recent years. Nature helps to purify air through the medium of wind, rain, oxidation and diffusion, and man can do much to check its pollution by insisting on cleanliness and absence of dust in rooms, and on the rooms being well lighted.

Composition of Air. Let us first consider the composition of pure air and the things which subsequently render it impure.

The most important constituents are nitrogen, oxygen and carbon dioxide, being roughly four-fifths, one-fifth and 0·04 per cent. respectively.

Actually a precise statement of the composition of pure air is not possible, since it is a mechanical mixture of gases varying according to the locality, latitude, altitude and other conditions, not (as is the case with water) a chemical combination of gases always in one set ratio.

Water vapour is usually present in a natural sample of air in quantities varying (by volume) from 1·2 to 5 per cent., so that it is usually considered best to state the composition of the air, excluding the water vapour.

Humphrey (in the *Scientific Monthly*) gave the following as a fair example of analysis of *dry* air in a rural district, but in spite of the decimals, they must still be considered as approximate:

Percentages by Volume

Nitrogen	78·03
Oxygen	20·99
CO_2	0·03
Argon	0·9323
Neon	0·0018
Krypton	0·0001
Helium	0·0005
Xenon	0·000009
Ozone	0·00006
Hydrogen	0·01

Another investigator (Hann) has stated that the percentage of oxygen present may vary from 20·44 per cent. at the equator to 20·80 per cent. at 30° N. and 20·94 per cent. at 70° N., other constituents varying in a more or less corresponding manner.

Oxygen. Oxygen is an element which combines with nearly all other elements. It is found in the soil, and it is also the principal constituent of water, of which it forms 89 per cent. by weight. It is absolutely necessary to life, its removal from the air, or even a substantial lessening of its proportion, causing death by suffocation. It is necessary for the processes of combustion, and also for the production of artificial light, except electric light. One could not live long in pure oxygen, but doses of it are administered by doctors to patients for short periods in extreme cases.

The nitrogen in the air acts as a diluting influence upon the oxygen. It is itself quite incapable of supporting animal life, but is an essential food for vegetable life.

Carbon Dioxide. Carbonic acid gas, or carbon dioxide, though so small in proportion to the quantities of the oxygen and nitrogen in the air, is second in importance only to the oxygen. On its presence depends the existence of all vegetable life. It is a compound of oxygen and carbon, and is usually formed at the expense of the oxygen in the air and of carbon derived from various sources, chiefly animal respiration and the combustion of carbonaceous matter. It is also given off as a product of fermentation and putrefaction. An eminent scientist calculated that volcanoes give off ten times as much carbon dioxide as is derived from all other sources. It is vital to the life of plants, forming their largest food factor. Under the influence of sunlight, they absorb and decompose it, retaining the carbon and giving off the oxygen again, but at night the process stops.

Standards of Purity. Because, in buildings, CO_2 is usually present at the expense of oxygen, it is usually taken as an index to its impurity, a high percentage of CO_2 being taken as indicating deficiency in oxygen and increase in the impurities usually accompanying respiration. It is by no means an infallible test, and the air of a mineral-water factory may be very heavily charged with CO_2 without any harmful effect on the workers, owing to the fact that there is no appreciable reduction in oxygen content or increase in organic or gaseous impurities. Nevertheless, in the absence of any really convenient index to the condition of the air, it remains a widely used standard of purity.

Medical men consider that, to be efficient, a ventilating scheme should be capable of keeping the percentage of CO_2 (if due to

respiration) below the limit of 0·06 per cent., and that air, in which the percentage of CO_2 is greater than this, is likely to be detrimental to the health if breathed continuously in confined spaces.

Humidity. Water vapour, due to evaporation from the surface of land and sea, is always present to some extent in air, but the amount which the air can keep in suspension depends upon the temperature of the air. If the air is suspending the greatest amount which it can at that temperature the air is said to be "saturated". Any fall in temperature will then result in the formation of mist, rain or dew, according to the height at which this occurs.

Percentage of Humidity. The moisture content of the air is usually measured as a "percentage of humidity", the state of saturation representing 100 per cent., while, of course, absolutely dry air would show 0 per cent. humidity.

The Hygrometer. The "hygrometer", used to measure humidity, is usually a "wet and dry bulb" thermometer, though other forms are also in use. Too dry an atmosphere inside the building gives rise to discomfort owing to its drying effect on the skin, while a humid atmosphere is apt to accentuate the excess of warmth in an overheated room by preventing the sweat glands from functioning. The evaporation of sweat from the skin normally enables the body to rid itself of excess heat. If, on the other hand, the air is too cold, too much humidity will allow the heat to leave the body too rapidly. This effect is very noticeable out of doors when snow is lying on the ground. With the thermometer at (say) 31° F., the air is dry and few complain of the cold, but let the temperature rise to 33° F. and the snow begin to thaw, the air soon becomes charged with moisture and far more complaints of the cold will be heard.

Argon, neon, krypton, helium and xenon are comparatively newly-discovered gases. They have no known effect on the animal economy, though new uses are constantly being found for them in science and commerce. As far as ventilation is concerned, these gases may be taken as forming, together with the greater volume of nitrogen, the diluting agent, without which the oxygen would be too strong for human lungs.

Ozone. In the pure air of mountain tops, or near the sea, one finds just a trace of ozone, which is a concentrated form of oxygen produced principally by electric discharges during thunder-storms, the evaporation of sea-water, and the action of certain types of vegetation, particularly fresh and salt water growths. It is also produced artificially by means of electrical discharges, a fact that

is sometimes taken advantage of in the practice of ventilation. Ozone possesses both positive and negative properties. Thus it renders the air healthful and invigorating, while on the other hand it acts as a disinfectant, killing harmful germs and acting as a strong deodorant.

Impurities. Hydrogen has been given as a gas generally present in the air. In such tiny proportion as 0·01 per cent. it does no harm, but in larger proportions should be regarded as an impurity, due probably to the decomposition of organic matter or (in houses) to leakage from gas pipes.

The air usually contains small quantities of one or other of the following gases, and in measurable quantities they should be considered impurities:

Oxides and acids of nitrogen, due to thunderstorms and plant life.

Hydrocarbons, sulphuretted hydrogen, sulphur dioxide, sulphurous and sulphuric acid, chlorine, hydrochloric acid and various ammonia compounds, mainly due to decomposition of organic matter or manufacturing processes, but seldom originating inside the dwelling and of course petrol fumes.

Carbon Monoxide. Carbon monoxide (the miners' "Firedamp") is similar to carbon dioxide in its constituents but differing in ratio and in practically every other respect. It is formed by incomplete combustion, emanations from the earth, certain manufacturing processes, and in other ways. Unlike carbon dioxide, it is lighter than air, combustible, and is a dangerous poison of a "cumulative" nature—that is to say, a daily dose so small as to be unnoticed may, if repeated day after day, result in serious illness or death, while 1 per cent. in the air of a room is enough to cause coma and death on a quite short exposure.

Methane. In the neighbourhood of low-lying marshy land, carburetted hydrogen or methane, also known as "marsh gas", may be found. It is not usually found in or near the dwelling in sufficient quantities to be dangerous.

Dust in the Atmosphere. In addition to gases, minute particles of dust are always present. If one places oneself in a dark room and makes just a pinhole through which a ray of sunlight can pass, one can see these fine particles floating about in the streak of light. Among these matters are particles of fine sand, dried mud, carbon from smoke, iron rust, volcanic dust and other inorganic items, as well as organic impurities, such as fragments of horse litter, hairs, spiders' webs, spores of fungi, pollen, etc.

It is said that some of the finer particles from an eruption travel round the earth twice before finally settling.

Such particles of dust—if sufficiently finely divided and of an innocuous nature—so far from being harmful, help to diffuse the light and warmth of the sun.

Bacteria. There are also always in the air numbers of micro-organisms, known as bacteria or bacilli, or (more popularly) as microbes. These organisms are very minute, it being possible to get a number equal to one hundred times the population of London on 1 square inch. They reproduce very rapidly, it having been stated by eminent bacteriologists that a single microbe gives rise to a progeny equal to about four times the population of London in twenty-four hours. They are not necessarily harmful, but the greater the number in any sample of air, the greater the likelihood of the presence of pathogenic or disease-bearing organisms. For all the processes of agriculture they are essential. Their presence in the soil is necessary for the growth of crops, and without their aid the farmer could not ripen his cheese or make his butter. They are necessary, in fact, in the soil, in the manure heaps, in the barn and in the dairy.

Bacteria are usually found in the air, attached to particles of organic matter, so that the importance of keeping the air of dwellings as free as possible from dust is self-evident.

Effect of Respiration. In the process of respiration, air is inhaled into the lungs, the oxygen being brought into contact with the blood. A large part of the oxygen is converted into carbon dioxide. In the course of twenty-four hours the average man gives off a quantity of carbon dioxide containing as much as a half-pound of carbon. Moisture is also given off to the extent of from about 6 to 27 ounces in twenty-four hours. Organic matter and minute quantities of ammonia are also given off.

Effect of Combustion. In the processes of combustion, among the impurities given off are carbon dioxide and moisture; unconsumed carbon; carbon monoxide, due to imperfect combustion, particularly from coal gas and coke fires; also sulphuric acid and sulphuretted hydrogen from gas which has not been properly purified. It is mainly these last two impurities which are answerable for spoiling pictures, the bindings of books and wallpapers.

Standards of Air Change. In dealing with ventilation some standard of air change is necessary. It must be remembered that the object of ventilation is not merely to keep the air pure, but to prevent excess of moisture from accumulating and to prevent excess of body heat, as well as to maintain the supply of oxygen and to keep down the harmful bacteria or other impurities. In fact, it is generally found that the physical condition of the air is

more important in the judgment of the average person than its chemical purity.

As stated earlier, CO_2 is usually taken as a standard of impurity, 0·06 per cent. being looked upon as a reasonable maximum allowance, i.e. 0·6 cubic feet in 1000 cubic feet. The air of an average town may be taken as containing 0·4 cubic feet in 1000 cubic feet, and the average adult is said to give off about 0·6 cubic feet of the gas in one hour. At this rate he will, in twenty minutes, raise to the allowable limit of impurity 1000 cubic feet of air, and so should be provided with about 3000 cubic feet of air per hour. This fact is often put another way, to the effect that he should be given 1000 cubic feet of space and the air should be changed three times an hour.

B.S. Code of Practice. This should be looked on as the ideal, rather than a standard, requirement, and the Ministry of Works allowance for dwellings is only 600 cubic feet of air per hour per person for average-sized living and bedrooms, with 2000 cubic feet per hour in the kitchen, if cooking is for up to six persons.

The investigations of the Ministry of Works into ventilation are now published as the "British Standard Code of Practice in Ventilation". It is issued by the British Standards Institution under the aegis of the Ministry of Works. Students who wish to go further into details of recommended rates of air supply to various types of building and apartment than these pages permit, might well obtain and study the code.

Air Space and Change of Air. It must be remembered that a good deal of accidental ventilation takes place through badly-fitting doors and windows and that a large displacement of air takes place each time a door is used.

The change of air is more important than the space occupied, and it has been shown that apartments with a large amount of cubic space per head and slow change of air are less healthy than those with less space and more frequent change, provided that draughts are not caused. In calculating the quantity of air required, each gas jet, when gas is used, can be regarded as equal to one human being in its effect on the purity of the air.

In calculating the cubic space for this purpose the air space over a height of 12 feet should be ignored. Suppose, for example, that the space required for a certain room is 7200 cubic feet and that the room is to be 14 feet high. A floor area of $\frac{7200}{14}$, or 515 square feet, would give this capacity but would not be satisfactory from the point of view of ventilation. The usable height is 12 feet,

so that the area should be $\frac{7200}{12}$, or 600 square feet. A room 30 feet by 20 feet would meet the case.

Customary Allowances. The following figures will give an idea of the customary allowances of cubic space per head: common lodging-houses*: rooms occupied at night only, 300 cubic feet; rooms occupied by day as well as at night, 400 cubic feet; Metropolitan police officers' quarters, 450—cells, 800; army barracks, 600; factories, 400; hospitals for adults, 2000; ditto for children, 1500; bakehouses, 500.

Figures such as these are not a satisfactory guide to good ventilation without a second figure of the number of air changes per hour to be given. For this reason certain licensing authorities, the London County Council among them, require ventilating arrangements capable of providing 1000 cubic feet of fresh air to each occupant (counting seating accommodation) of cinemas, theatres, music halls and similar public buildings, before granting the licence.

Conditions of Satisfactory Ventilation. There are certain conditions which any really satisfactory system of ventilation should fulfil. They may be stated briefly as follows:

1. Fresh air must be admitted or injected and the vitiated air allowed to escape, be extracted, or expelled.

2. The quantity of air supplied and the velocity of its admission should be under control.

3. The change of air should be thorough, no stagnant corners being left.

4. There should be no draughts.

5. The incoming air should be clean and humid and not scorched or deprived of its moisture by defective methods of warming it before admission.

6. The temperature of the air should be uniform and under control.

Probably there is no system which absolutely fulfils all these conditions at all times, but the principal systems in use and their respective advantages and disadvantages will be fully described.

Natural Principles of Ventilation. There are certain natural principles which greatly assist the ventilating engineer, namely:

* The term "common lodging-house" is rather vague. There is no English statutory definition of it, but from legal decisions it may be taken to be that class of lodging-house in which persons of the poorer class are received for short periods, and, although strangers to one another, are allowed to sleep in a common dormitory.

1. The fact that warm air is lighter than cool and tends to rise.
2. Moist air is lighter than dry air and also tends to rise.
3. Air in motion is less dense than still air.
4. Gases at different density tend to diffuse.

Main Classification of Ventilation Schemes. There are three principal schemes of ventilation in common use:

(*a*) The natural scheme.
(*b*) The vacuum (or extraction) scheme.
(*c*) The plenum (or propulsion) scheme.

Schemes (*b*) and (*c*) are sometimes described as "mechanical" schemes. A natural scheme is one in which inlets and outlets are placed in suitable positions and nature is allowed to do the rest. This system is simple and economical. It will generally give reasonably good results in a building which provides approximately 1000 cubic feet of air space per person, but there is very little control.

A vacuum or extraction scheme is one where the vitiated air is drawn out artificially—usually at outlets near the ceiling or roof—and the fresh air is allowed to make its own way in through inlets at a lower level.

Air Conditioning. In a plenum or propulsion scheme the fresh air is pumped in and the vitiated air is allowed to make its own way out, or is drawn out by a fan or pump of smaller power than that at the inlet, when it is usually described as a "balanced scheme". The plenum scheme usually combines air warming and "conditioning" and is therefore a much more complex and expensive system both to install and to maintain.

The vacuum scheme is to be recommended, in preference to the natural, for buildings in which there is some reduction in the allowance of cubic air space per person. It usually entails merely the hurrying up of the air currents caused by the natural principles. It requires but little initial outlay, while running expenses also are low.

Downward and Upward Plenum Ventilation. The plenum scheme, on the other hand, is usually arranged to provide downward ventilation, and the natural principles have then to be overcome before the fresh air (introduced at ceiling level) reaches the occupants.

The plenum system is sometimes adapted to upward ventilation (which enables the natural principles to be utilised), but not every building is suitable to its use, while the expense of installation is usually greater.

The Council Chamber of the London County Council provides an excellent example of upward plenum ventilation, the inlets

being well-spaced low down around the walls and across the floor, by making use of fixed furniture to mask the inlets.

The plenum scheme, either upward or downward, is essentially the scheme to be recommended for a closely packed building such as a theatre or cinema. Owing to its complexity it would be unwise to advise its installation unless it can be done on thoroughly sound lines, and there will be an income sufficient to guarantee efficient maintenance.

Disadvantages of Natural Schemes. The objections to the natural system are (1) the source of supply of fresh air is not under control; (2) the incoming air is not so readily cleansed and humidified; (3) the volume, temperature, and velocity of incoming air are not under control; and (4) it is apt to prove a draughty system.

On the other hand, it is simple and inexpensive, costing very little for maintenance, and doors and windows may be freely opened without disorganising the system.

Disadvantage of Vacuum or Extraction Schemes. Few objections are raised against the vacuum scheme, except that, if installed in a closely packed public building, it does not give sufficient control to the "condition" of the air and is apt to cause draughts.

Disadvantages of Plenum or Propulsion Schemes. The objections often put forward against the plenum scheme are as follows: (1) the downward system is opposed to natural laws and necessitates vitiated air being re-breathed; (2) the flues and ducts are very difficult to keep clean, and become foul from dust and germs; (3) the air is apt to be delivered overheated, causing great discomfort about the head, while the extraction of vitiated air near the floor level is apt to cause coldness to the feet; (4) the incoming air is liable to be fouled by the roasting of dust on the heating batteries; (5) the doors and windows must be kept closed; and (6) the system requires skilled supervision.

On the other hand, the system is under control as to quantity of air supplied, its temperature, and its humidity; it is claimed to keep out fog and to keep rooms more free from dust than the natural system, though it is doubtful if this claim can be fully substantiated. It is argued that pure air is conducted down to the nostrils, and so to the lungs, before passing over contaminating bodies, but this is also a matter of serious contention owing to the natural tendency of warmed vitiated air to rise.

Natural Ventilation. Having dealt broadly with the principles of systems, let us next consider their details, starting with the natural system.

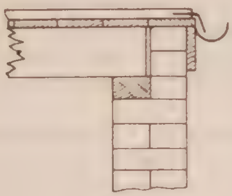
In doing so, it will be well to have regard first to the ordinary

dwelling-house, in which there should be three essential considerations: (1) the rooms containing sanitary fittings should be grouped together floor over floor and isolated from the rest of the house, so far as possible, by approaching them through a ventilated lobby. If circumstances permit, this lobby should have a good window on each of two opposite sides so as to ensure its through ventilation; failing this, one large window should be provided. The grouping together of the sanitary fittings in this way also greatly simplifies the drainage. (2) The building should be ventilated as a whole by providing a staircase as central as possible. If there be a fireplace in the hall, the upward current will be assisted. The outlet at the top may be in either of the following forms: (*a*) a lantern light having side lights to open, (*b*) an opening skylight, or (*c*) a good-sized window with opening sashes or casements.

The ground-floor air inlet to this central air stream may be a special louvred panel (Fig. 69) or other inlet or may be an openable fanlight (similar to Fig. 52), over the hall door or just an ordinary openable window. (3) Each room opening out from this central shaft or air stream can then be separately ventilated by one or other of the methods which follow, into this central duct or may be dealt with independently. In either case the central air stream will be a valuable aid to the ventilation of the individual rooms.

Nature helps to purify air through the medium of wind, rain, oxidation of organic impurities, diffusion, and the interaction, before referred to, between the vegetable and animal kingdoms.

Inlet and Outlet Controls. In a natural system, no mechanical appliances are used except controls for the inlets and outlets and simple aids to nature, such as revolving cowls worked by the wind. It should be stated at once that a good deal of ventilation takes place in a well-arranged building with no special provision for ventilation whatever. This applies particularly to the comparatively small rooms of dwelling-houses, as fresh air enters, and vitiated air leaves, via badly fitting doors and windows, even when kept shut, while a certain amount of air percolates through walls, ceiling, etc. This unintentional ventilation becomes less in proportion as the room or building becomes larger, as of course a door 2½ feet by 6 feet will admit a man equally well into a large ballroom as into the smallest room in the house, while even window space is usually based not on cubic capacity but a proportion of the floor area. It is uncommon to find any systematic method of ventilation adopted for the rooms of private houses when they are provided with the conventional 9-inch $\times$ 9-inch flue of an



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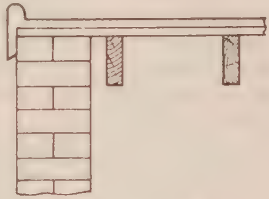

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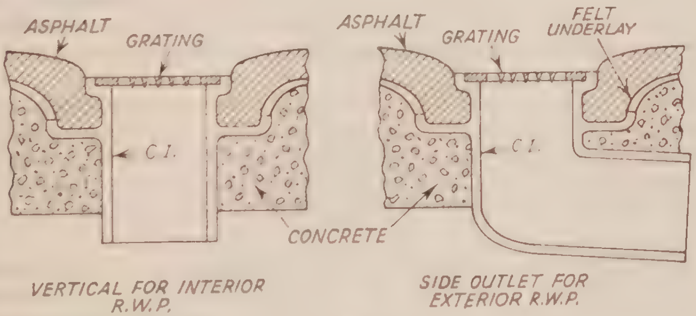
ASPHALT
GRATING
C.I.
CONCRETE
VERTICAL FOR INTERIOR R.W.P.
ASPHALT
GRATING
FELT UNDERLAY
C.I.
SIDE OUTLET FOR EXTERIOR R.W.P.

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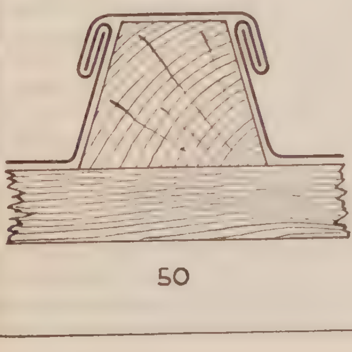

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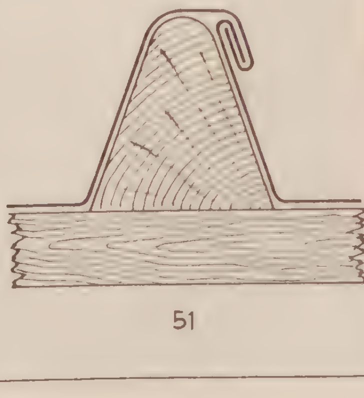

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open fire-place. If, however, special ventilation is introduced, it will almost certainly be the natural system.

In this system, the outlets for vitiated air are put as high as possible and inlets for fresh air reasonably low, though not so low as to cause discomfort by draught or by the diffusion of the incoming air with that of the room. The incoming air is sometimes filtered and warmed.

The forms of inlet are not very numerous. The windows may be either intentional or unintentional inlets. Indeed, even if closed, it is probable that a good deal of vitiated air from a warm room will pass out through badly fitting joinery at the top while fresh air will enter at the crevices of the bottom half. Of course, the hygienically-minded householder will want to increase the flow of air in both directions when conditions warrant it and windows should be provided by the architect of such size and type that they can be opened without causing undue draught or letting in the weather during rain.

When casement windows are adopted, there is much to be said in favour of putting part of the glass above the level of a transome, one or more of these transome lights (hinged at the top) opening outwards to allow for ventilation at night or during rain when the casements below will probably be closed, is shown in Figs. 71 and 72.

During fine weather, if casements are hinged on alternate sides as in Figs. 72 and 73, they can be opened in such a way as to shield the effect of a stiff breeze or to catch the light air and bring it inside, according to the outside conditions. Figs. 52a and 52b show the effect of hinging a transome light at bottom and top respectively.

The first type is used more in schools and semi-public buildings, and is often provided with hopper sides of glass or metal to cause incoming air to flow upwards and diffuse with the warm air in the room before reaching the person of occupants.

The second form throws off most of the rain but does not control direction. It acts chiefly as an air outlet.

Sash windows, illustrated in Fig. 53, allow the occupant excellent control of ventilation.

Deep Bead or Hospital Type Ventilators on Sash Windows. Sash windows, illustrated in Fig. 53, allow the occupant excellent control of ventilation, especially if a deep bead or draught-board about 3 inches wide is fitted on the inside of the bottom rail of the lower sash. This enables the lower sash to be raised so as to admit air in an upward direction between the meeting rails of the

two sashes, without the liability to draught lower down. In the sketch the glass is shown in section by thick lines and the course of the incoming air indicated by arrows. This is the most convenient type of inlet for a dwelling-house or ordinary office. This principle was introduced in the eighteenth century by Whitehurst, but the subject of ventilation was not then considered so important and it fell into disuse. Nearly a century later the system was reintroduced by Dr. Hinckes-Bird, and it is now usually known by his name, or as the "deep bead" or "Hospital type" ventilator.

Common modifications of this type are (*a*) to place the deep bead inside at the top of the upper sash. (*b*) The provision of a loose "draught board", which can be placed under the bottom sash when raised a few inches (instead of the deep bead). (*c*) The modification of the deep bead by constructing it in two members, the lower one clearing the sash and the upper one touching it for a width of perhaps 1 inch only. This is found to prevent draughts and to reduce the risk of the lower sash "binding" in damp weather.

The Sheringham Valve. Another form of inlet is the Sheringham valve, shown in section by Fig. 55. It consists of a small iron flap with fan-shaped ends to prevent draught, and is hinged at the lower edge A; it can be opened or closed to varying extents by means of cords and pulleys and is so shaped that the incoming air is given an upward direction. The outer face of the opening through the wall is protected by a grating. This form of inlet is often found in use in bedrooms.

"Cooper's" Ventilator. Cooper's ventilator is sometimes used as an inlet. Fig. 56 shows it to be a circular "hit and miss" ventilator in glass. A series of openings is shown by firm and dotted lines respectively. Those shown by firm lines are cut in a circular piece of glass fixed at its centre so that it can be made to rotate in the direction shown by the arrowhead. The openings shown by dotted lines are formed in the window pane. On rotating the circular disc the openings can be made partially or entirely to coincide, thus providing a less or greater amount of air inlet. Fig. 54 shows a straight ventilator of the same type, capable of being opened or closed by means of cords and pulleys. "Hit and miss" ventilators are almost always found over the doors of railway carriages, though there, of course, they are of wood.

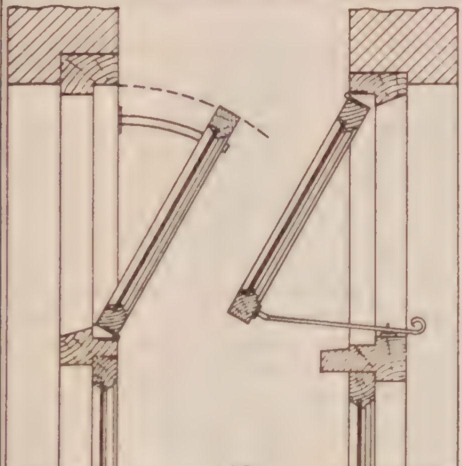
Louvred Panels. Another form of window inlet is the "louvred" pane; that is to say, an arrangement of strips of glass working like a Venetian blind and capable of being opened or closed. This

arrangement is sometimes adapted as a wood or metal louvred panel in an outside wall instead of in a window.

The Tobin Tube. A form of inlet found more often in a public building than in a private house, though sometimes met with in billiard rooms, is that known as the Tobin tube. It is often found in a neglected and dusty condition and is misused as a receptacle for litter, especially in schoolrooms. For this reason it is looked upon with disfavour by most present-day architects. It is of various forms and constructed of various materials. Thus it can extend from the floor level to a height of about 5 feet 6 inches or 6 feet above the floor, or it may be of a bracket form not reaching to the floor. Again, it may have a filter, a regulator, and a lid, or it may have neither of these accessories. Further, it can be of wood, zinc or sheet-iron. At the top of Fig. 57 is shown a muslin bag filter. Sometimes an inclined sheet of tightly drawn muslin is used instead. The object in either case is to obtain a large area of filtering material; a piece of muslin across the top of the tube would be speedily clogged up owing to its affording such a small filtering surface. The main trouble with Tobin tubes is that the householder seldom makes use of the facilities provided for washing or cleaning the filter, while the rest of the tube is difficult of access for cleansing.

Figs. 58 and 59 show a proprietary form of an inlet, namely Colt's "Constant Flow" ventilator, which controls the rate of inflow of fresh air, whether the external conditions are light air, medium wind or strong gale. The internal face is shown in Fig. 59, looking very little different to an ordinary upward louvred air grating. The external face can be an ordinary air brick or an iron-louvred grating with louvres downwards to keep out the rain.

The working parts are shown in Fig. 58. These consist essentially of lightly hung, hinged double louvres, shaped rather like a roof with a flat top. The pivots or rockers are of plastic material, silent in action and will not wear or require lubrication. With a light air entering from the outside the louvres remain stationary and the air flow is not affected (left-hand diagram) but as the wind increases its force, the louvres tilt more and more until the silencing pads touch the louvre below and the air passage is nearly closed. This reduced quantity of air, entering the chamber at high pressure, fans out owing to the shape of the air passages, and enters the room with quantity and velocity almost identical in all conditions of outside weather. It is suitable for insertion into an opening in either solid or cavity walls, a rust-proofed iron tube of rectangular cross-section bridging the gap in the latter case and



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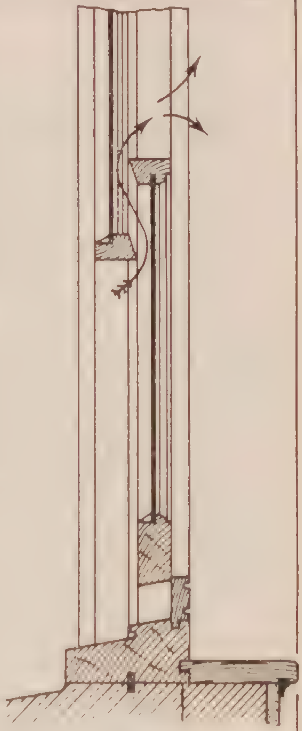
A B

TRANSOME LIGHTS–HINGED AT BOTTOM TO OPEN INWARDS – HINGED AT TOP TO OPEN OUTWARDS



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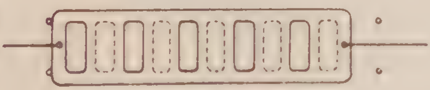

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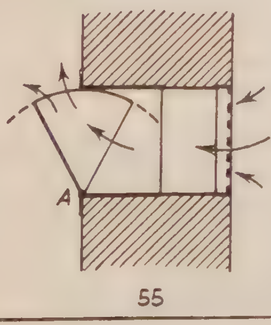

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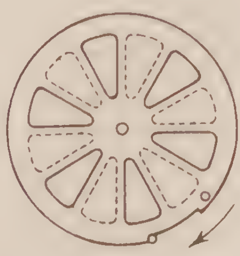

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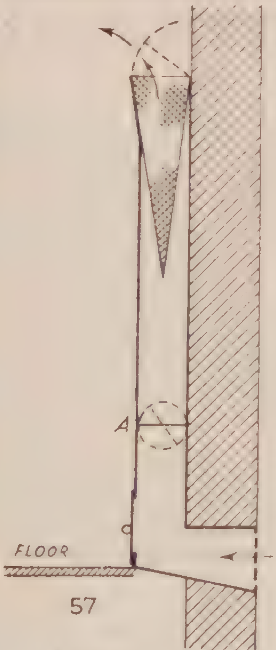
preventing air from the cavity being drawn into the room for ventilating purposes.

As can be seen from the form of construction, the louvres work equally well if air is moving outwards instead of inwards, but it is as an inlet that its main advantage would be felt.

Ventilating Radiators. Houses, or other buildings, centrally heated by hot water or steam, may be provided with ventilating radiators as fresh air inlets. When this is done, care should be taken that the air ducts or cavities are made accessible for cleansing at regular intervals by the domestic staff. Any access plates or doors should be removable by the turning of a single button or thumbscrew. If a screwdriver is necessary for the operation it is most unlikely that the necessary cleansing will ever get done. Ventilating radiators may be (*a*) of the ordinary type, placed in front of an opening (controlled by a hit and miss grating) in an external wall and provided with shields or deflectors to prevent direct draughts (as shown in Fig. 60); (*b*) of "indirect" type such as is indicated in Fig. 61; or (*c*) of the "direct-indirect" type shown in Fig. 62. Type (*a*) gives very little control and is apt to be draughty. It is, indeed, more an adaptation of the ordinary form of radiator than one specially designed to aid the ventilation. Type (*b*) will allow for warming the incoming air only. The air already in the room cannot be warmed by its aid except by dilution. It is sometimes placed in a cavity or chamber under the floor or behind wall panelling, so that no part of the apparatus is visible from the room except the inlet grating. Type (*c*) is the most satisfactory owing to the complete control that is provided. By closing the outer damper, the outer air is excluded, and the clean air already in a room or hall can be warmed up to any desired extent. When the occupants arrive, the inner shutter may be closed and the outer damper opened, when the freshness of the air may be maintained without lowering its temperature or causing unpleasant draughts.

Ventilating Grates. The same principle exactly is employed in the "Galton System" and in the earlier ventilating grates and stoves introduced in the seventeenth century.

Fig. 64 shows a plan and section of the ventilating grate designed for the old War Office, in Pall Mall, by Sir Douglas Galton. The first figure shows a vertical section of this grate. Cold air enters through a grating at the outside face of the wall and circulates in an air-warming chamber behind the fire. It then passes upwards and around the smoke flue, S, and is admitted into the room by means of two louvred openings at the side of the mantel.



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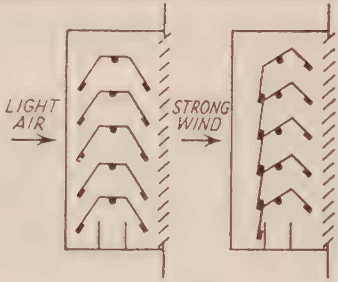
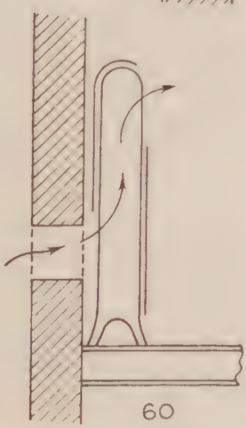


58

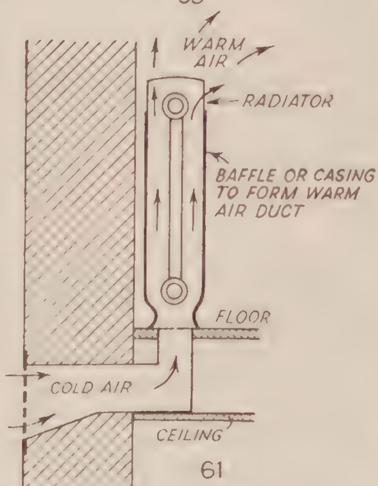
COLT CONSTANT FLOW VENTILATOR

59



60

RADIATOR WITH VENTILATING BAFFLE PLATES



61

It will be seen that the fresh air enters through a grating at hearth level, and that the iron back of the fireplace has projecting gills, GG, projecting into the hot-air chamber in order to increase the warming power.

The air ducts are marked DD. The disadvantage of most such types of ventilating stove is the difficulty of keeping the air-ducts clean, while the sweeping of the smoke flues also is not easy, and the type has never become popular in domestic architecture.

Modern Adaptations of the Galton System. An adaptation of the Galton system is being reintroduced by one or two modern stove manufacturers, in the form of an open fire with back boiler. An enclosed supply of air to the fire and a second enclosed supply leading to air ovens beside the flue and delivering into tubes or ducts leading up to the bedroom or bedrooms immediately above, which thus get a certain amount of "background" heating. This can be "topped up", if necessary, by lighting a small gas fire or switching on an electric heater in the bedrooms. If the air supply is led in from a clean source, this encourages a flow of clean warm air into the two bedrooms, using the residual warmth of the fire on the floor below. The method is also being recommended by the "Post-War Building Studies, No. 19, Heating and Ventilation", published by H.M.S.O. Other types of ventilating grate will be found in the chapter on "Warming".

Prevention of Draught. Whatever form of inlet ventilator is employed in natural ventilation, it is important that the inlets should be carefully placed to prevent draughts and that they should be well distributed around the room in order to aid the natural diffusion, caused by the difference in density between the incoming cool air and the warm air already in the room. The judicious placing of inlets and outlets is a matter of great importance in all schemes of ventilation, in order to prevent stagnation of air in any part—particularly if the room be planned on irregular lines.

The outlets in a natural scheme of ventilation should be as near the ceiling as possible, so that the warm moist vitiated air from the occupants' lungs may rise and pass straight out. The cooler air entering nearer the floor level will then tend to diffuse (owing to its greater density) so that occupants in any part of the room may get the benefit of the fresh air, without the annoyance of draughts.

Several of the forms of inlet ventilator are suitable also as outlets if suitably placed.

For example, the "hit and miss" grating is often placed in an external wall near the ceiling of spare bedrooms, boxrooms,

W.C's, etc., to act as an outlet. It forms rather a crude ventilator, and should be protected against driving rain by the use of a louvred iron grating on the outer face of the wall, instead of by the usual plain form.

If the "hit and miss" grating is placed over a doorway opening into the main staircase, or into a corridor or passage leading thereto, an efficient means of outlet ventilation will be provided without the fear of driving wind or rain causing discomfort. The value of the main staircase, used as a ventilating shaft in this way, is greatly augmented if there is a radiator or fireplace in the hall at the foot, with inlet ventilation at ground level and an outlet in the form of a louvred panel, a window, skylight or lantern light made to open at or near roof level.

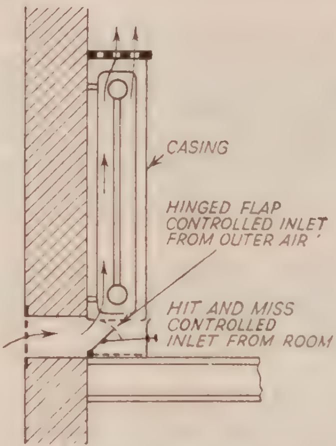
The Cooper's (or glass "hit and miss") ventilator, the louvred pane and the louvred wall panel can all be used as either inlets or outlets according to their position with regard to the other openings and the direction of the wind or air currents outside the building.

The Arnott Valve. The "Arnott valve" shown in Fig. 63 is often found in old buildings, but is not very popular in modern ones, perhaps because the wall decorations are apt to get discoloured in the neighbourhood of the grating.

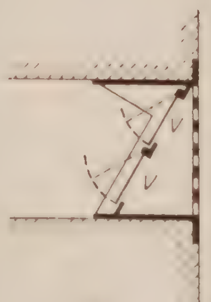
It consists of a valve leading into either a smoke flue or, better, a separate ventilating flue carried up alongside a chimney flue, so as to ensure its being kept warm and so induce an upward current through it. It should be placed as high as possible. If a smoke flue is used, a flap valve, like that shown, is the best. It consists of a grating with valves behind it, marked VV in the sketch. They are very light and hinged at the top edge. Talc is often used, but has the disadvantage of rattling, and thick silk is therefore better, as flaps of such material are noiseless. The dotted lines indicate their movements.

The Arnott valve should not be used in any chimney breast unless there is certain to be a good up-draught, or there will be some risk of interfering with the drawing power of the fire. The cause of the "smoky" appearance of the wall around the valve is not due to smoke, but to the air currents of vitiated air passing out, impinging upon the surface and depositing tiny particles of dust—the same action as is often noticed on the wall above a hot-water radiator. The grating should therefore be placed in the centre of a painted panel smooth enough to resist the deposit of dust or to be cleaned down easily at intervals.

Ceiling Frets. Another form of outlet is the ceiling fret or grid,



VENTILATING RADIATOR
(DIRECT-INDIRECT TYPE)
62



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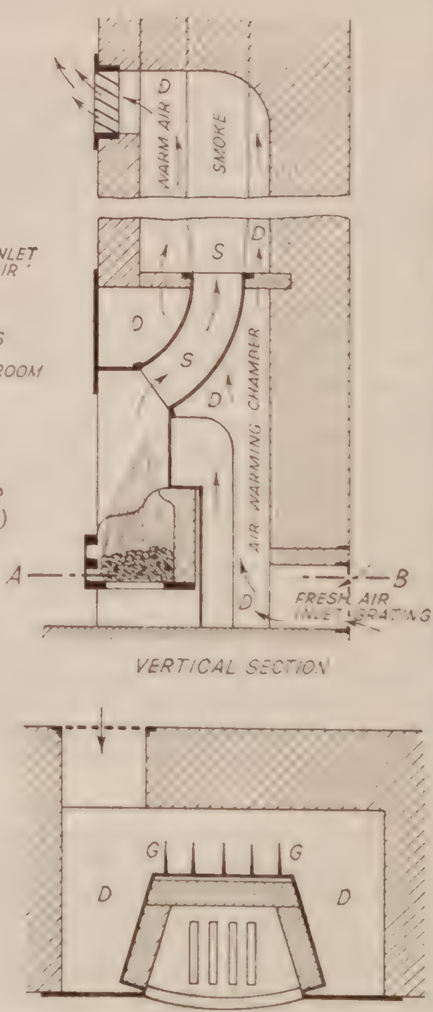
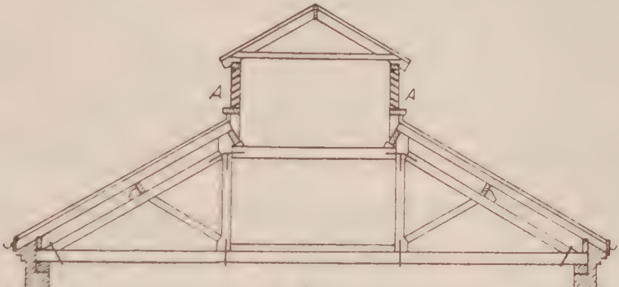


SECTIONAL PLAN A-B
64



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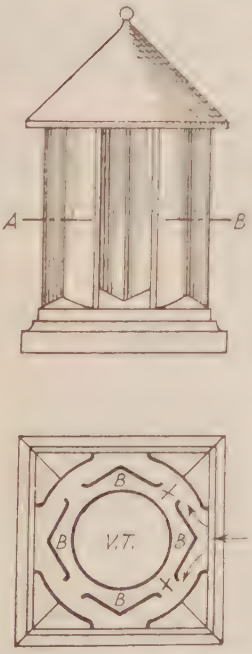
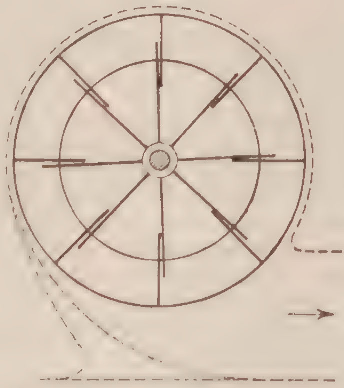


SECTION ON A–B

65



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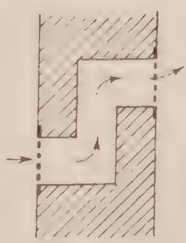


68

69

leading to a flue by means of a tube between the floor and the ceiling under it, a valve being put at the junction with the flue if it is one from a fireplace.

When gas was the principal form of illuminant in use, the fret was often formed into a plaster centre flower over a gas pendant. The heat from the gas then aided the extraction effect.

Electric light fittings do not lend themselves quite so kindly to this type of treatment, nor is so much heat formed with an equal amount of lighting.

Louvred Turrets and Ridge Ventilators. Buildings consisting of one storey only can be ventilated by connecting up a ceiling panel or grid with a louvred turret or cowl on the ridge. These may be designed by the architect and put together by the builder as in Fig. 66 or (as is more usually done) commercial forms may be selected from the stock of the builder's merchant or manufacturer. These are commonly built up of thin plates of pressed steel or copper with fixings, aprons and flashings all incorporated, so that very little trouble is experienced by the builder in making a sound watertight job.

Manufacturers' catalogues will reveal the large number of available types, some being merely fixed baffles or louvred turrets, while others are provided with vanes to swing round with the wind (like the "lobster-back" cowl) or to revolve and rotate an extractor apparatus (like the Archimedian revolving cowl). The revolving forms should be provided with a ball race and a sealed oil container, so that a fair supply of oil may be run in on the rare occasions that such a fitting will receive attention. As such attention is apt to be very uncertain, it is a moot point whether it is wise to use mechanical cowls.

Unit and Central Ventilating Schemes. The methods described so far are all "unit" ventilating devices—that is to say, only one room is dealt with. The arrangement can be made into a "central" ventilating scheme by collecting up the outlets from the different rooms, though this sometimes leads to vitiated air from one room beating down into another, and is better avoided unless there is an extractor fan on the main outlet.

Fig. 65 shows one form of ventilating turret and illustrates the general principle upon which most will be found to work. It shows an elevation and a horizontal section of it on the line AB. In the centre is a ventilating tube, V.T., and around it two sets of baffle plates, so arranged that the openings between those forming one set do not coincide with those of the other set. Its action is as follows: Assume the wind to be blowing from the right-hand

side, as shown by the arrowhead. It will pass through the opening between the outer plates and strike against the inner baffle marked B, which splits up the current into two different directions as shown by arrowheads. In rushing past the openings XX air will be drawn out from the space between V.T. and the inner baffle plates, tending to cause a partial vacuum in the tube V.T., which is not carried right up to the top. As nature abhors a vacuum, air will be drawn out of the ventilating tube. This series of events occurs no matter in which direction the wind may be blowing.

Size of Ventilating Openings. The size of inlet and outlet ventilators is a matter upon which there is a good deal of disagreement.

The ideal has been given as 1000 cubic feet of air changed every twenty minutes, but it is not at all an easy matter to guarantee such a figure in a natural scheme, however carefully the details may be worked out. Probably there is no part of the sanitary engineer's work where so much compromise exists between the ideal and the actual working conditions.

Ventilation Formulae. A rough rule of thumb often used is that 1 square foot of inlet should be provided for every six occupants—i.e. 24 square inches per person.

Another rule (used in conjunction with the ideal exchange of air before mentioned) is derived from the fact that the quantity of a fluid discharged by a pipe or duct is equal to its sectional area multiplied by the velocity of flow, or

$$S = VAT,$$

in which

S = air space or quantity of air dealt with in cubic feet.
V = velocity of the air in feet per second.
A = sectional area of inlet or outlet in square feet.
T = time in seconds.

The velocity at which air will enter and leave a room in a natural scheme is naturally very variable, depending on the relative temperature of the air inside and out, on the state of the barometer, the wind pressure and a variety of other items outside the control of the occupants.

With average conditions, however, it will be found fairly easy to obtain a velocity of 3 feet per second at the outlet in a natural scheme, owing to the warm moist vitiated air rising towards the outlet near the ceiling and the fact that the air currents outside flowing past the orifice are likely to be more vigorous than those lower down near the inlet.

If we assume that no air enters or leaves the room except through the prescribed channels (which in practice is certainly not the case), then if the inlets are made the same size as the outlets, the cool fresh air will enter at the same velocity, and in average circumstances the occupants will complain of draughts. Now a draught is not easily defined—the best definition, perhaps, being that it is "a current of air at such a velocity, temperature and humidity as to cause discomfort to the occupants of a room". The average person in normal health will usually begin to complain if the air enters faster than 2 feet per second. To get the ideal conditions of 1000 cubic feet of air per person in twenty minutes with a velocity not exceeding 2 feet per second the sectional area of inlet must be such that

$$\begin{aligned} S &= VAT, \\ 1000 &= 2 \times A \times (20 \times 60), \\ A &= \frac{1000}{2 \times 20 \times 60} \\ &= \tfrac{5}{12} \text{ of a square foot per person,} \end{aligned}$$

and 1 square foot of inlet would be sufficient for about $2\frac{2}{5}$ persons, very different to the rule of thumb mentioned earlier.

Accidental Ventilation. The fact is that 1 square foot for six people allows for the "accidental" ventilation taking place in a fair-sized room—that is air entering and leaving through badly fitting joinery, smoke flues, percolating through the walls, floor, ceiling, etc. The amount of ventilation taking place in this rather haphazard fashion is so great that very few living rooms (provided they have an open grate with a smoke flue) have any definite ventilation openings. The velocity at the throat of a well-constructed flue, with a good fire burning, will amount to 5 or 6 feet per second, so it is easy to see what a help to ventilation the old-fashioned open grate can be.

As was explained earlier, however, this "accidental" ventilation, while considerable in the case of a small living room, becomes proportionately less and less as the room gets larger, until with a hall such as that of a cinema, with its absence of windows, it is relatively so small that it should be neglected altogether.

There is often confusion in the minds of students of sanitation with regard to the relative sizes of inlets and outlets. If the air enters and leaves only via the definitely arranged inlets and outlets, the area of the inlet (in a natural scheme) should be about $1\frac{1}{2}$ times that of the outlet, in order to reduce the velocity of the incoming air. Owing to so much air entering by unauthorised

routes, it is quite common practice in small rooms (up to say 10,000 cubic feet capacity) to provide outlet ventilators only and to let the fresh air enter where it will. With larger rooms, when both inlets and outlets are provided, the ratio may be inlets to outlets 1:1 or $1:1\frac{1}{2}$, because part of the actual air inlet is unmeasured and unmeasurable.

Velocity in Air Ducts. When the building is in actual existence and the ventilation scheme is working, the air velocity can be measured (if necessary) with an anemometer, which is a lightly hung fan or propeller screw geared up to a needle or indicator working on a dial. If the building is in prospect only, the probable velocity through an air shaft or duct can be estimated approximately as follows.

The formula is based on that for the velocity of falling bodies ($v = \sqrt{2gh}$), but has to be modified to allow for the difference in temperature between the air in the tube and the outer air; also for the fact that air expands $\frac{1}{491}$, or 0·002, of its volume for each degree Fahrenheit and for *friction*.

The formula therefore becomes

$$V = c\sqrt{2gCHT},$$

in which

V = velocity in feet per second.

c = coefficient of friction = 0·5 to 0·75 according to the sectional form and smoothness of the tube and the number of bends in it.

g = the gravitational unit = 32·2.

C = coefficient of expansion = 0·002 or $\frac{1}{491}$.

H = height in feet from the inlet to the outlet of tube or flue.

T = difference in temperature, in degrees Fahrenheit, between air in tube and the air outside.

Therefore

$$V = c\sqrt{2 \times 32{\cdot}2 \times 0{\cdot}002 \times H \times T},$$

or simplifying,

$$V = c\sqrt{0{\cdot}129\,HT}.$$

Sometimes written

$$V = c\sqrt{\frac{HT}{8}}.$$

The rougher the surface of the tube or flue, the lower the value of c. Again, angles tend to lower its value, therefore the best type of tube or flue is one of circular section with easy curves for

changes of direction. Right angles seriously check the velocity; one right angle in the length would reduce V to $0{\cdot}5V$ and two right angles would reduce it to $0{\cdot}25V$.

In applying the natural system to a public hall, the best form of inlet would be the ventilating radiator (if centrally heated) or perhaps a row of Colt's Constant-Flow ventilators as inlets, if there are no radiators, while the best form of outlet would be a ventilating turret over the centre of the hall, or two if need be. From the ceiling a wood-lined shaft could be formed, leading up to a turret formed above the roof as in Fig. 66, with small doors to close the shaft at ceiling level by means of cords and pulleys. The turret might be formed with louvred sides; or it might contain an extract ventilator such as that illustrated in Fig. 65.

Buildings of one storey are much more easily ventilated than those of several storeys. Thus, schools are better dealt with if arranged on the pavilion plan, that is to say, in a series of one-storey rectangular buildings connected by corridors, after the manner of an infectious diseases hospital. Such a case might be dealt with by using ventilating radiators or hopper sashes as inlets, with extract ventilators at roof level.

Ventilating Stoves. Large rooms without radiators, in which a stove in the centre of the floor is not a disadvantage, may be provided with a ventilating stove. Hospitals sometimes use this system.

Fig. 84 shows a section of one of the best-known types, known as the Manchester stove. The cold air supply is conducted to the stove by a duct formed in the floor, with access plates to enable periodical cleaning to take place. It then rises up around the back of the fire and passes through tubes, shown in section by circles, placed in such a position as to get the full heat of the fire. Thence it passes upwards through a grating formed in the top of the stove, as shown by the sketch. The smoke from the fire escapes by a descending flue to a duct (also provided with access plates for sweeping) formed in the floor and leading to a chimney. While it is desirable to have a room warmed to a reasonable temperature, care must be taken to prevent the air being unduly warmed, too high a temperature causing its partial decomposition and robbing it of its humidity. Additional inlet ventilators can be provided low down, between or under the beds, and they may take the form of openings through the wall, guarded by gratings on the outside face and by "hit and miss" plates on the inside so as to regulate the supply of air. Ventilating radiators and hopper sashes are also often used for such buildings. In single-storey

buildings exhaust ventilators can be put in the roof, while in buildings of more than one storey, the outlets can be collected to proper ventilating flues.

In the case of stables and similar buildings, it is undesirable to have any projecting features. Air inlets can be formed in the thickness of the wall, as shown in Fig. 68. The "kink" in the inlet breaks the inrush of the air, and the inlet can be controlled on the inside by "hit and miss" plates. The inlets in such buildings are fairly low down. For commoner work air bricks are often provided as inlets and in such case a special form of brick is desirable. One of the best forms has conical holes with the larger ends at the inside of the buildings, so as to reduce the velocity of the incoming air.

In ordinary workshops, such as a builder's or decorator's, no elaborate provision is made for ventilation. In ordinary buildings, the spaces between the ends of the rafters, where they rest on the walls, are bricked up. It is a common practice to leave them open in the case of workshops and this makes some provision for ventilation. In the absence of anything of a mechanical nature, other alternatives are the provision of a reasonable number of air bricks or gratings around the walls, or louvres in the roof.

Laundries present especial difficulties and cannot be ventilated adequately without mechanical aid.

Effect of Weather on Natural Ventilation. It should be noted that any system of natural ventilation is always somewhat at the mercy of atmospheric conditions and cannot be regarded as constant or uniform in action, even though it may be the best system available for the particular case in question.

Probably the best argument is that natural ventilation should be adopted if it appears unlikely that the number of occupants will much exceed one person to every 1000 cubic feet of air space, for in that case it is comparatively easy to ensure the necessary changes by natural means.

If, however, there is likely to be a certain amount of overcrowding (judging by the ideal conditions), it is time to think of helping the natural principles by putting a fan on the outlet. Outlet shafts have sometimes been aided by means of gas, steam or water jets inside them, or hot water or steam coils are put in the shafts to increase the current of air through them. The value of heat for inducing a current in this way has long been recognised, a seventeenth-century example of its use being on record.

Vacuum Ventilating Schemes. The use of fans in conjunction with schemes of ventilation is generally regarded as a comparatively

modern idea, but this is not so. Their value was known to the Romans, for Agricola describes the injection of fresh air into mines by means of rotary fans. It is equally certain that their use was unknown for very many centuries in England, and the manner of introduction of the fan into this country for ventilating purposes is of some interest.

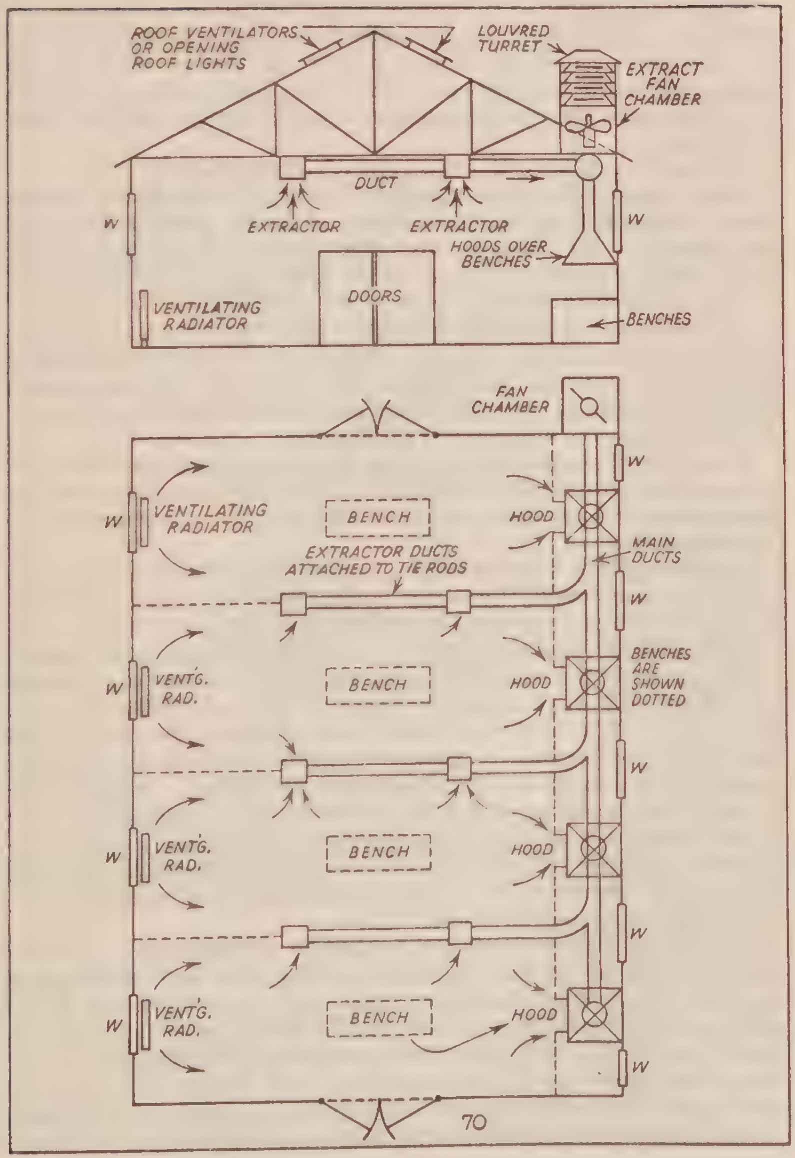
Sir Christopher Wren having been unsuccessful in ventilating the old Houses of Parliament satisfactorily, the matter was entrusted to a Dr. Desaguliers, a Frenchmen, who had lived in England from his childhood. He made many experiments, and in 1734 installed a ventilating fan over the ceiling of the House. It was of wood, about 7 feet in diameter by 1 foot thick and had twelve straight blades reaching from the circumference to within about 1 foot of the axle. It was placed upright, with the inlet at the centre of its side and the outlet at the top, and was rotated by a man turning a handle. This fan was so successful that it remained in use for over three-quarters of a century.

Types of Ventilating Fan. Rotary fans are in common use now for ventilating purposes, but they are almost always of metal. It is interesting to note that one of the best-known types is of very similar construction to that just referred to. Fig. 67 shows a section of what is termed a fan wheel. It is similar in form to a paddle wheel. The thick lines show the blades in section and they are connected at their sides to flat rims, one of which is shown by the two circles in the sketch. The wheel is housed in a casing of steel, one or both sides being partly open to admit the air, and the outlet or inlet can be horizontal, as shown in the sketch, or vertical, or at any angle of elevation. The dotted lines show the housing. Such a fan is often termed a blower and is only used in large ventilating schemes.

There are various other types of ventilating fan. For example in Fig. 75, the first one shows a "box" type fan. There is a circular rim, of the section shown at B in the small sketch, and the blades are of curved section, with a fairly large area. Each blade is straight at one edge and curved at the other. The small sketch gives a section on the line AB.

The "propeller" type has smaller blades, rather similar to a ship's screw or an aeroplane propeller, rounded off at the outer ends of the blades.

The other type shown in Fig. 75 is termed a disc wheel. It has flat adjustable blades set at an angle to the face of the frame. The small sketch shows a section through one blade, on the line CD, the blade being shown in section by a thick line.


ROOF VENTILATORS OR OPENING ROOF LIGHTS
LOUVRED TURRET
EXTRACT FAN CHAMBER
DUCT
W
EXTRACTOR
EXTRACTOR
W
HOODS OVER BENCHES
DOORS
VENTILATING RADIATOR
BENCHES
FAN CHAMBER
W
VENTILATING RADIATOR
BENCH
HOOD
MAIN DUCTS
EXTRACTOR DUCTS ATTACHED TO TIE RODS
W
BENCHES ARE SHOWN DOTTED
VENT'G. RAD.
BENCH
HOOD
VENT'G. RAD.
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HOOD
VENT'G. RAD.
BENCH
HOOD
70

If the fan is placed at the entrance to a long air duct where much resistance will be met, the propeller type is apt to drive the air out into the duct on the outer ends of the blades, while in the centre (where the linear speed of the blade is less) the air is apt to creep back into the room, undoing (in part, at any rate) the work of the fan.

For such conditions, the box type is to be preferred.

In any case, the friction offered by bends in air ducts is a serious disadvantage and should be reduced as far as possible by using easy bends to the ducts or air tubes instead of sharp or right-angled bends, and by seeing that the inner radius of such bends is at least equal to the diameter of the tube or duct.

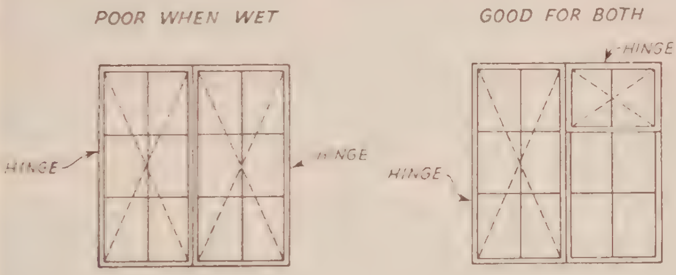
Various types of portable or table "fans" are in use, but these are mere air agitators, and are often termed rotary punkahs, a name which expresses their action more correctly. In some cases they are attached to ozonisers, small instruments for the production of ozone by means of electrical discharges.

A somewhat similar device is the fixed, overhead punkah with arms or blades rotated by electricity. They are sometimes seen in restaurants, and provide a means of agitating the air and preventing stagnation.

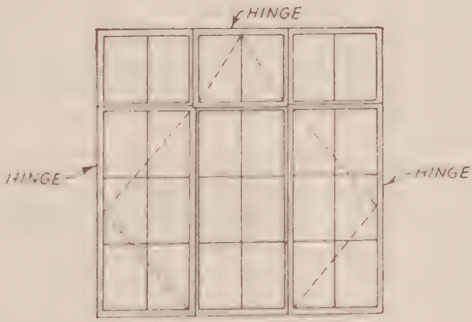
Ventilating fans may be driven by either electric motor, steam, gas, oil or occasionally by water power, but the most convenient for small and medium sized installations is the electric fan.

Application of Vacuum System. Generally speaking one would expect to apply the natural system where there is ample air space per person, say in the neighbourhood of 500 to 1000 cubic feet per person. Where the available space is less, say 350 to 500 cubic feet per person, it becomes desirable to help the natural principles by putting an extractor fan on the outlet. Where there is gross overcrowding, say 350 cubic feet per person or less, or where specially "conditioned" air is required for any purpose, the vacuum system would tend to produce draughty conditions, and the plenum system with at least some degree of warming the incoming air becomes desirable.

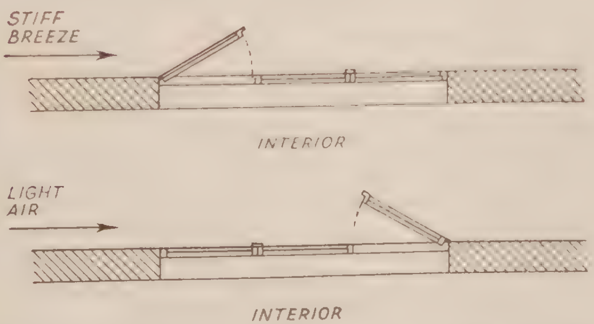
Example of Vacuum Scheme Applied to a Workshop. Assume that the diagram on Fig. 70 represents the plan and section of a one-storey workshop, centrally heated by low-pressure hot water with radiators, and that a good deal of light vapour and dust is formed at the benches. As the by-products are light, some will escape the hoods and rise toward the roof, hence small branch ducts are led from the main duct over the benches and are suspended from the roof tie bars with small extractor grids where shown.


POOR WHEN WET
GOOD FOR BOTH
HINGE
HINGE
HINGE
HINGE

71


HINGE
HINGE
HINGE

72


STIFF
BREEZE
INTERIOR
LIGHT
AIR
INTERIOR

73

The warmed air entering at the ventilating radiators will circulate partly by convection and partly by the mechanical extraction effect of the fan chamber. The louvred outlet turret is placed well away from the inlet radiators, so there should be little chance of the exhausted air being returned through the inlet.

Ridge ventilators (such as Fig. 66) or roof ventilators or opening roof lights (such as indicated in Fig. 70) might be found desirable to remove vapours or light dust missed by the extract ducts on the tie rods.

Plenum Ventilating Schemes. When a room or building is intended to be particularly closely occupied, such as with theatres, music halls, cinemas and the like, it is most difficult to obtain a sufficient change of air by the vacuum or extraction system without causing acute discomfort in cold weather by draughts, and the "Plenum" or "Propulsion" system may be recommended. It will generally be found, in such cases, that fans are used on both the inlet and the outlet, but as the extractor fan is of smaller power, the air in the room is still slightly over normal pressure and it is still known as a plenum scheme, or it may be described as a "balanced scheme".

The great point about this system is that the air in the room is under pressure, so that any leakages must be outward, thus lessening the risk of draughts. For this reason the outlets are slightly less powerful than the inlets, whereas in the vacuum system, the air pressure in the building is less than the external or normal air pressure, and any leakages are likely to be inwards, increasing the risks of draughts. The plenum system may, with certain limitations, be upwards, but the normal plenum scheme involves downward ventilation, the inlets being in or near the ceiling while outlets are actually in the floor or are in the walls near floor level, as illustrated diagrammatically in Fig. 74.

Example of Balanced Ventilation. This figure is not to be regarded as a working drawing of the ventilation of a theatre, as the local licensing regulations would have to be consulted. Usually in such a building, if downward ventilation is adopted, there will be outlets at the sides or back of the stage, leading into the main outlet ducts, so as to prevent a current of air passing from the stage to the auditorium. In some schemes the lowering of the safety curtain is made to alter the ventilating controls, securing separate ventilation of the stage and auditorium, and so to prevent an outbreak of fire being driven towards the latter.

The reason for the normal downward flow in plenum ventilation is that warmed air passed in from the fan chamber at the usual

inlet level near the floor would tend to rise up to the ceiling and pass out at the outlets without the occupants getting any benefit, either of the warmth or of the fresh air.

By reversing the process and driving in the warm air at ceiling level, it spreads out in layers, gradually descending as it cools till it reaches the level of the occupants, finally passing out through outlets in the walls a foot or two above floor level. Windows have to be kept closed and doors opened as little as possible, to prevent the loss of the descending layers of warmed air before it reaches the occupants. This goes against the grain with the average healthy-minded lover of fresh air, and educational authorities seldom advocate its use in schools on account of its tendency to accustom the children to permanently closed windows.

The Upward Plenum System. If it is desired to reverse the flow of warmed air, admitting it at the inlets near the floor to pass out near ceiling level, the only way to do this satisfactorily is to distribute the inlets at many points over the floor area, which is seldom convenient except where there is fixed furniture—such as the fixed desks of a council chamber or the fixed, tip-up stalls in a theatre or cinema. When the inlets are well distributed in this way, it is utilised by the occupants in its upward path, and it is then immaterial if it rises up and passes out through open windows or outlet ventilators near ceiling level.

No diagram is given showing the adaptation of the plenum system to upward ventilation, but the reader can easily contrive one from Fig. 74 by linking the main conditioned air duct with inlets at the sides of the stage, and with an extra number of floor "mushrooms" (or similar openings) under the stalls and gallery seats, and taking the ceiling openings to the extractor fan chamber.

Air Conditioning. This term is generally applied to systems in which, in addition to the fan chamber and heating batteries, there are also two or three other chambers for altering the condition of the incoming air, such as filters, humidifiers and the like. There is no set definition of what air treatment justifies the name. It is just a term and to describe a system which includes more than replacement of vitiated air with warmed fresh air.

The system, as often carried out, provides for propelling into the building, by mechanical means, warmed or cooled, sterilised, filtered, humidified or dehumidified, ozonised and and sometimes even perfumed air, which passes along large horizontal ducts and through vertical flues into the rooms, the vitiated air being extracted through other vertical flues leading to a main trunk outlet.

The design of such an installation is a matter calling for very great skill and is essentially one for a specialist. The plenum or balanced system, usually with some degree of air-conditioning, has been adopted in many large public buildings and business premises.

Intake and Fan Chamber. Briefly, the system is arranged as follows. The fresh air is drawn, by means of a powerful fan, through a humidifying screen or filter, into a large main duct situated in the basement, at the entrance to which is usually a heating battery. From the main duct, flues lead up to the various rooms, controlled by dampers or valves. Usually the ducts are in duplicate, one for cold air and one for warm, arrangements being provided for mixing the air from the two. The fresh-air intake should be placed where the cleanest supply is available—usually high up, but care must be taken to avoid a position where smoke or soot from chimneys is likely to be drawn in.

It may even be found that a more satisfactory supply is obtained near street level than at roof level in a crowded city area, owing to this cause.

Air-conditioning Chambers. The fresh-air duct then passes through one of many varieties of humidifying filter, which serves the double purpose of moistening the air and filtering it. Or the filter chamber and the humidifying chambers may be kept separate.

It is generally found that only the larger and heavier impurities are intercepted, the finer particles passing straight through.

The use of screens kept moist by sprays in one form or another is by no means new, one having been installed at the Houses of Parliament in 1835.

Principal Types of Filter. Air filters may be divided into four main groups:

(*a*) Wet filters of various types or "air washers".

(*b*) Dry fabric type filters.

(*c*) Dry "throw-away" type filters, using cotton wool, glass fibre or similar material, on a frame of wire netting or other form. In this case, the filtering medium is discarded as soon as it becomes soiled and is replaced with fresh.

(*d*) Viscous filters, using a special grade of oil on zigzag or baffle-shaped blades.

Wet Filters. One form of wet filter consists of a large inclined drum, covered all round and at one end with fibre. The open end leads into the main duct, the covered lower end dipping into a water trough in such a manner as to keep all the fibre constantly

wet. In all cases the water in the troughs is being constantly changed so as to wash away the impurities, but, notwithstanding this, the types of screen just described have the common disadvantage that the material to some extent harbours impurities. A type, therefore, which has not this drawback is to be preferred. Other forms of wet filters consist of banks of sprays, some with coarse jets, some with very fine, producing a wet mist rather than a spray. Baffle plates made of fine, lead-coated steel, or of ribbed or fluted glass are often placed across the chamber to intercept the air stream and eliminate the dust or other foreign matter. Such filters also act as humidifying chambers if the temperature of the water jets is raised a little.

Dry Fabric Filters may consist of muslin, serge, cellulose-wadding and similar materials stretched on metal frames in such a way as to present the largest possible intercepting surface and so prevent the velocity of the air being too greatly retarded.

Such filters need fairly frequent cleansing.

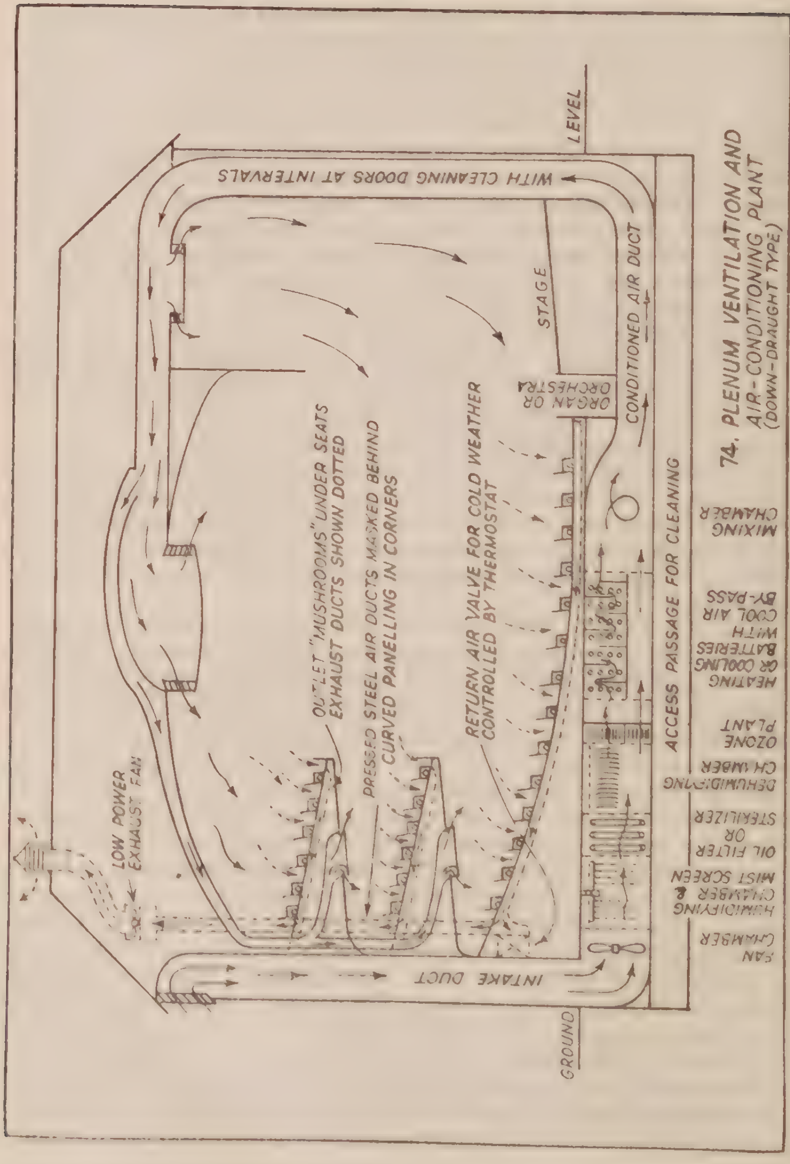
"*Throw-away*" *Filters* are the same in principle but the filtering medium is cotton wool, glass fibre or some similar material on a frame of some sort so as to be readily removed and replaced with fresh medium as soon as it becomes soiled. The saving in labour with this type to some extent counteracts the cost of the fresh material.

Oil Air Filters. Perhaps the most popular form of air filter to-day is the self-cleaning oil filter, in which a sort of revolving roller blind "shutter" is placed across the fresh-air intake duct. The "shutter" consists of metal louvres or baffle plates, one behind the other, which, on turning a handle, can be made to dip into an oil bath in the base of the chamber, leaving a thin film of oil on each louvre. A special grade of odourless oil is used, which will act like a flypaper, any suspended matter in the air, impinging upon the baffles or louvres, adhering to the oily surfaces, a fresh coating being given each day by rotating the "shutters".

Sometimes the oil is replaced by a mixture of glycerine and antiseptic, which thus acts as a steriliser, but, of course, a very mild antiseptic without any unpleasant odour must be employed.

Humidifying Chambers. The humidifying chamber generally takes the form of a mist screen. The general principle upon which this works is usually one of the following:

In the vertical intake shaft an arrangement of water jets is provided, these being so arranged as to divide the water finely and distribute it thoroughly over the horizontal area. Below the water jets a number of sheets of galvanised corrugated iron are put, the



74. PLENUM VENTILATION AND AIR-CONDITIONING PLANT (DOWN-DRAUGHT TYPE)

width of the sheets being vertical and the length either horizontal or inclined.

The sheets are about 1 inch apart, right across the shaft. The air is drawn through the spray formed by the jets and so humidified. It then passes between the wet corrugated sheets, the corrugations ensuring its continued contact with the wet sides, which thus further arrest the impurities. The base of the shaft is arranged with a trapped draining outlet, so that the water can escape without loss of air or risk of pollution.

A mist screen is sometimes formed by a series of water jets discharging upwards.

Still another, and a rather better, form has a hanging vertical water pipe, terminated by a four-armed fixed sprinkler, the outlets pointing downwards at an angle and discharging on to a loose revolving propeller. The effect is to cause the propeller to revolve at a high velocity, thereby dividing the water into a very fine mist.

In such screens there is a liability for the jets to get frozen in winter, but this is avoided by putting a heating battery, of fairly large pipes, round the shaft just above the jets.

In some cases the fans discharge into a single large brick or concrete duct, rendered in cement, with the floor laid to falls, and stand pipes for the purpose of washing out the duct. From the main duct, which should be well lighted, single subsidiary ducts go vertically to supply the various rooms. In such a single duct system the bases of the subsidiary ducts are provided with heating batteries fixed opposite the upper half of the inlet, the lower part being free to pass cold air. Dampers are provided to regulate the temperature. Thus, if the damper is down, all the air passes through the heater. If it is up, no air passing into the duct is warmed; if partly up or down, some air will be warmed and some not, making it possible to regulate the quantity of each and so control the temperature. In this case, the arrangement of the inlet to the room is very simple, as shown in Fig. 76. There should be no sharp angles in the length of the duct, and its entrance to the room should form an easy curve. The sketch shows the duct plastered to make it smooth, and shows the inlet to the room marked by a frame with a very open and readily removable grating, often of brass wire netting.

Heating Batteries. The heaters are often of ordinary wrought-iron pipes, but in order to get greater radiating surface they are frequently of what are termed gilled pipes, having a section similar to that shown in Fig. 77. In summer, the warmth of the air can

be tempered by passing it through large crates filled with broken ice or by passing it through the "heating batteries" cooled down by water from an ammonia refrigerating plant instead of being heated by the boiler.

On the other hand, if the double duct system is used, the main duct is divided horizontally, the upper duct taking cold air and the lower warm. Similarly, double subsidiary ducts are used. In this case the heating may be done by a battery of steam pipes adjacent to the fan or blower, the heater at the foot of each minor duct being unnecessary. The temperature is kept under control by mixing dampers, placed near the inlet to the room as a rule. These are of various types, but a form in very general use is shown diagrammatically by Fig. 79, which is an outline section through the heads of two subsidiary ducts. The damper D is in the form of a metal cylinder, loosely hinged to the division between the ducts. It can be raised or lowered till it occupies either of the positions shown by the two dotted circles. Thus, when in the position of the upper circle, the cold air is entirely shut off. It can be regulated to admit any proportion of hot and cold air.

Duct Sizes. The sectional area of the main duct should exceed the combined sectional areas of the minor ones, so that it may form a sort of storage reservoir for filtered air. There should be no obstructions on the floor and all angles should be rounded to facilitate cleansing, access doors being provided at convenient points for the purpose. It is often the case that the main duct is not kept clean and dust allowed to accumulate on the heating batteries. The high temperature of the latter roasts the dust, causing an unpleasant odour in the air. The heating batteries, too, are often at such a high temperature that the air is robbed of the humidity which such pains have been taken to give it. Of course, on the other hand, if air is too humid, there is a feeling of oppression, caused by the checking of evaporation of moisture from the skin, and for this reason a dehumidifying chamber is often added. The air drying may be done by a chemical moisture absorber, or, more conveniently, by freezing the moisture out of the air by an ammonia refrigeration plant (the moisture being deposited as frost), or by sprays of ice-cold water, entering on opposite sides of the air duct, which condense the surplus moisture and carry it off with the spray water.

The use of a dehumidifier needs very careful adjustment and oversight, or too much of the humidity may be removed.

The power used should be as far as possible from the rooms to be ventilated, as the ducts are powerful conductors of sound.

Thermostatic Control. The automatic regulation of temperature is often adopted in such schemes of ventilation. This is accomplished by the use of thermostats, of which there are many types. One consists of two thin corrugated metal plates, fastened together at the edges to form a hollow disc, which is filled with a volatile liquid capable of boiling at a very low temperature (58° or 60° F.), creating a pressure which expands the disc and so causes it to exert force. At 70° F. a pressure of 6 lb. per square inch is given, and this is enough to operate the mechanism of the dampers. Other types of thermostat are actuated by the expansion or contraction of various metals, vulcanised rubber, etc.

Thermostatic Re-circulation Control. In many large modern plenum ventilating and conditioning installations, thermostatic control is applied also to the extract ducts. Doors or valves are placed in cross tubes, running from the vitiated or extract air ducts and connected to the inlet duct just before the fan chamber. If the air in the hall becomes too cool, the thermostat opens the return air valve and 25 per cent. or thereabouts of the exhaust air is returned to the conditioning plant to be re-used, thus maintaining the temperature without increasing the fuel bill. A further drop in temperature might result in 50 per cent. or even 75 per cent. of the exhaust air being returned for re-circulation, but 75 per cent. should be the absolute maximum permitted, so that at least 25 per cent. of fresh air is drawn in, even in cold weather, while the return air valve should not be permitted at all, unless there is a very complete conditioning plant with an ozonating chamber for the addition of ozone, or a sterilising chamber.

Planning Inlets and Outlets. The positions of the inlets and outlets for the air is a matter of very great importance in order to avoid dead or stagnant corners to the room.

If placed in the walls both inlets and outlets might be put in the same wall, an internal one for preference. They are used at both ends of the room to prevent short-circuiting. The inlet should take the form of a detachable grating about one-third larger in area than the sectional area of the duct, the current being directed somewhat upwards as shown in Fig. 76.

In some cases the inlets are in the form of almost invisible gratings at the side of a suspended ceiling panel, the warmed fresh air descending in layers, until it reaches the occupants, after which it passes down through numerous small mushroom-like outlets in the floor to the main outlet ducts. If floor outlets of this type would prove obstructive flat floor gratings may be used instead.

The Upward Plenum System. When the plenum system is worked on the "upward" plan, there is danger of short-circuiting the warmed air unless the inlets are thoroughly well distributed about the room. In a comparatively small room there will be sufficient distribution if the inlets are arranged in all four walls near floor level, but in a large hall the inlets would need to be distributed about the floor as well. if the air currents are to be prevented from passing straight up to the outlets before the occupants get the benefit. This can only be done in a hall containing a good deal of fixed furniture, such as that in the Council Chamber of the London County Council, which is ventilated in this manner.

If an extract fan is used as well as the plenum fan, it should be of a lower power, so that the air in the room is kept under slight pressure.

The outlet gratings, if in or near the floor, should be made larger than the inlets, so that the velocity of the outgoing air is reduced to 2 or 3 feet per second. The incoming air can enter at from 4 to 6 feet per second if in the walls, or rather faster—say up to 10 feet per second—if in a ceiling panel of a lofty hall, and the air is changed about ten to twelve times an hour. The main extract shaft should be covered and have side outlets, a propeller being provided near the outlet to assist the extraction. It is important that this propeller should not be too powerful, or it will short-circuit the circulation of air in the rooms.

From the foregoing it will be seen that the system is one which, if used at all, should be installed when the building is being erected. It is, however, sometimes applied to an existing building, in which case the ducts are usually of light galvanised iron sheeting. The best form of section for such ducts is circular, this giving the least frictional resistance. All bends should be of large radius, at least equal to the diameter of the tube, and all junctions should be easy bends or of "Y" pattern.

In the case of factory buildings it is often applied in this way, a main duct running the length of the building, overhead and down the centre. From this, branches are taken at intervals towards the side-walls, but going only about half-way towards them and then bending slightly downwards. In some cases such a system is adopted merely for warming, the building getting its air by a natural system. In such a case a fan or blower wheel is installed, open at the sides for entrance of the air of the building, which is then blown through a heating battery.

It will be seen that the plenum system is complicated and costly. It is very liable to disorganisation by breakdowns, which makes it

desirable to put in the whole of the plant in duplicate. It is of the greatest importance that the instructions given for the management of the installation should be very carefully followed, many an installation having been greatly increased in efficiency by changes in the supervising staff. It is obvious that so complicated a system cannot be entrusted to any odd man, but must be put in the charge of a skilled mechanic, thoroughly conversant with all its details.

The system has been adopted to some extent in hospitals, but it seems singularly inappropriate for this purpose, with its closed doors and windows, when one considers the fact that for convalescence, as well as for the treatment of some diseases, as much "open air" as possible is desirable. There is a great difference between what is known as plenum air and the open air. The plenum system has sometimes been adopted for schools, but it is suggested that an abundance of fresh, untreated air is also very desirable for school children, while the practice of accustoming them to closed windows is one the advisability of which is seriously open to question.

Several novel features were possessed by a mechanical system introduced some years ago by Dr. Glover Lyon, one of which was the method of regulating the incoming air. The inlets were arranged along opposite sides of the room, forming a frieze, but having fronts readily removable for cleansing. No filters were used, and the air was both pumped in and extracted by means of fans. The fact that the velocity decreases as the distance from the fan is increased was taken advantage of and regulated spaces were pierced in the inlet ducts, the quantity and velocity of the incoming air, as well as the uniformity of its distribution, being thus kept well under control. The further from the fan, the larger the pierced opening, the same principle being adopted with the outlet. Openings of various sizes would of course look unsightly, but the system provides for this by masking the variation in size by appropriate architectural treatment.

The Hygrometer. Reference has already been made to the question of humidity, but it may be well to mention the way in which the degree of humidity is determined. This is done by means of an instrument termed a hygrometer, which is a sort of double thermometer. Two thermometers are placed side by side, and the bulb of one, which is wrapped in cotton wick, goes down into a small water reservoir. As evaporation causes loss of heat, the wet bulb thermometer will usually read the lower; but if the air is quite saturated they will read alike, for evaporation can then

not occur. Between the two thermometers is a scale giving the percentage of humidity, absolute saturation being, of course, 100. Another form of hygrometer is read by a needle on a circular dial and is more convenient, though perhaps not quite so precise.

Testing Ventilating Schemes. The tests for a ventilation scheme may be classified as

(*a*) Physical.
(*b*) Chemical.
(*c*) Biological.
(*d*) By the senses.

The first is to measure the cubic space and floor area per person. the sizes of inlet and outlet, take the velocity with the anemometer and then compare (with help of a formula if thought necessary) with the ideal allowance.

The second can be applied, in a rather rough and ready way, by the application of a test to determine the percentage of carbonic acid gas, which is a fairly good index of impurity. A sample of the air is taken as follows: Get a clean transparent glass bottle of about 10 oz. capacity and cram into it a clean, dry linen cloth or fill it with distilled water. Take the bottle into the room, the air of which is to be tested, and pull out the cloth or empty out the water and the air will rush in to take its place. Put into the bottle ½ oz. (or a tablespoonful) of clear lime water and shake it up: if the lime water becomes milky, there is an excess of carbonic acid gas present. This rough test was introduced many years ago by Dr. Angus Smith, a well-known authority on sanitary matters.

A more exhaustive examination is, of course, a matter for the chemist.

The third test is a matter for the bacteriologist, but it may be desirable for the sanitary engineer to take the samples. This is done by obtaining specially prepared gelatine discs attached to the bottom of wide flat stoppered jars. The stoppers are removed in the room whose air is to be tested, and the discs are left exposed for the number of seconds directed, the stoppers replaced, sealed with wax, packed in ice (unless within easy reach of the laboratory) and despatched with as little delay as possible. By proper cultivation, the specialist is able to tell, from the colonies of bacteria which result, not only the number of bacteria which were present per cubic centimetre in the air of the room tested, but also their nature.

The fourth method is mainly a matter of exercising the common powers of observation, by visiting the building during occupation with the apparatus in full swing and trying out the reaction on the

senses. Allowance must be made for the fact that the observer is probably entering from the fresh outer air after brisk exercise, so judgment should not be passed too quickly after entry. Neither should the observer sit in one position only, the comfort conditions and the presence or absence of draughts being sought for in various parts of the room.

Instruments used for Testing. The smoke of a cigarette may be a useful if rough guide to the existence and direction of draughts, while the use of a "Kata Thermometer" (designed by Sir Leonard Hill and shown in Fig. 78) is a great help. It is an instrument for measuring the heat-absorbing powers of a draught. It has only two index lines, while it is provided with a "finger stall" enabling a wet bulb reading to be taken as well as a dry one. To use it, the instrument is placed in a cup of warm water until the spirit rises into the top cistern. It is now hung in the part of the room to be tested, and the time taken for the spirit to fall from index 1 to index 2 is recorded with the help of a stop watch, first with the dry bulb, then with the wet finger stall slipped on. As the heat-absorbing power of a draught is due mainly to the relative temperature, humidity and velocity of the air currents, it makes a useful index to the comfort conditions when the readings are compared with tables calibrated from ideal conditions.

The Eupatheoscope and Eupatheostat. More elaborate instruments are the eupatheoscope and the eupatheostat, the second being combined with a thermostat for controlling the air and radiation temperatures.

The eupatheostat consists essentially of a pear-shaped bulb or body, electrically warmed up to the average temperature of the human body (not blood heat), so that the comfort conditions in radiant warmth can be recorded and allowed for, as well as convected heat (which is the principal agent tested by the Kata thermometer); while the larger size and the electrical connections make it possible to insert a thermostat in the pear-shaped body, to control the temperature by adding to or reducing the heat, radiant or otherwise, or by regulating the flow of warm or cold air through the air ducts, or by adjusting current supply to radiators.

The eupatheostat is not often employed, except as a permanent accessory to "all-electric" installations.

In comparing the cost of systems of ventilation, it is necessary to capitalise the cost of maintenance and add to it the initial cost, as the system which seems the more economical may possibly prove the more expensive.

Nearly a century ago, an essayist on this subject, Bernan,

delivered himself of some sage remarks which, in concluding this section, are worth repetition. He said: "Ventilation is a process so simple in itself, yet withal so delicate, as to be easily impeded or destroyed even by seemingly skilful arrangements to promote it; and more attempts have failed by aiming to produce the effects wholly by comparatively complex artificial means, than by relying on a simple modification of the natural process, which would have served the purpose as effectually".

CHAPTER V

THE BUILDING—ITS WARMING AND LIGHTING

Historical Note. As an introduction to this part of the subject, a brief historical note may be of interest.

The origin of fire is about as uncertain as the date of discovery of coal as a fuel. Innumerable other kinds of fuel have been used in ancient and modern times. For centuries, wood, peat, and turf were the staple fuels of Great Britain, but the consequent denuding of the land of timber led to a proclamation by Queen Elizabeth to the effect that no oak, ash, or beech tree that was 1 foot through at the stub and growing within 14 miles of the sea or of a navigable river, should be used as fuel for smelting iron.

It is believed that coal was known before Roman times, coal cinders having been found under Roman foundations in England. The word coal, also, is British—that is to say, of earlier than Anglo-Saxon date. In 1239 Henry III granted a charter to the inhabitants of Newcastle, permitting them to dig for coal, and at the end of that century it was imported into London. The smoke produced by burning it in improperly constructed grates caused such a prejudice against its use that in 1306 an Act was passed making it a capital offence to burn coal in the city of London, and there are records of execution for the offence.

Probably the first composite fuel used was that introduced by Sir Hugh Platt, an eminent sixteenth-century lawyer, who says, "to speake trulie of it, coal and cowdunge maketh a sweete and pleasing fier": a statement which seems open to question. In any case, and however "sweete and pleasing the fier", we have too much regard for the farmer and his craft to-day, to wish to warm our homes at the expense of the soil's fertility.

Ancient Methods of Warming Buildings. The methods of warming buildings are almost as numerous as the varieties of fuel. A favourite primitive method was a sort of stove or oven inside the room, stoked from the outside, this structure serving as couch by day and bed by night, the whole family often sleeping on the top of it. Examples could be seen in modern times among the poor of Russia, and the method has been used as far afield as Egypt and China.

According to Homer, the Greeks used fires in hearths for both warmth and light; they also used charcoal braziers. The Romans

used hypocausts, consisting of a sort of hollow floor with a space about 2 feet high, in which a fire was made, with pipes or flues up the walls to spread the heat, the openings into the rooms being in the form of lions' heads, and this method was used in Roman villas in England.

The forms of chimney, hearth, and fireplace have gone through great changes before reaching their present character.

In ancient British houses, the hearth was put in the middle of the hall so that as many as possible could get round it, and this practice was followed till as late as the fifteenth century, though at the time of the Norman Conquest the hearth was often placed against the wall, with a sort of pyramidal flue terminating in a hole in the outer face of it.

Generally speaking, from the Conquest to the time of Henry VIII, fireplaces were put on outside walls, but the Elizabethan architects put them on inside walls opposite the windows. Huge fireplaces were used, with large flues often put one behind the other, instead of side by side as nowadays.

Fires were at one time a great luxury in the house, the right to use the fire being sometimes bequeathed. Thus the will of one Richard Byrchett (1516) reads: "I will yt the sayd Nell my wyfe shal have ye chamber she lyes in and lyberte at ye fyer in the house; all yese things shal she have so long as she ys wido."

In order to consider the problems arising out of modern heating practice, it is necessary to recall some of the physics of the schoolroom.

Definition of Heat. Heat is a form of energy in the nature of waves through the ether or of vibration of the molecules of which a substance is composed. It may be formed in a variety of ways, but, for our present purpose, we may assume that it results from the combustion of some type of fuel, from the condensation of steam, from the friction or "resistance" which an electric current meets in a poor electric conductor or filament, from the processes taking place in the human body, from the vast stores of heat in the sun and in the interior of the earth.

Heat is necessary to our comfort and health and the range of variation in temperature to which the human body can accommodate itself is really remarkably small.

Measurement of Heat and Temperature. Heat has both quantity and intensity.

Quantity can be measured in Calories or British Thermal Units with a "calorimeter": intensity of heat is measured in degrees with a "thermometer" or "pyrometer".

The British Thermal Unit (or B.Th.U.) is that quantity of heat absorbed by 1 lb. of water when raised in temperature by 1° F. (strictly from 39° F. to 40° F.).

The Continental unit for technical use is the large Calorie, which may be described as the quantity of heat required to raise 1 kilo. of water 1° C.

The Gramme Calorie (or small calorie), consisting of the quantity of heat required to raise 1 gram of water 1° C., is seldom used by heating engineers and may be ignored.

1 B.Th.U. is equal to about 0·252 of a Calorie, while, reciprocally, 1 Calorie equals approximately 4 B.Th.U.

A "Therm" is a collective unit and equals 100,000 B.Th.U. There are several thermometer scales still in use, but the only two the heating engineers needs are the "Fahrenheit" and "Centigrade" scales.

Thermometer Scales. The Fahrenheit scale divides the interval between the freezing- and boiling-points of water at sea level into 180°, fixing "zero" at 32° of these units below the freezing-point of water, so that boiling-point becomes 212° F.

The "Centigrade" scale (used for scientific work in this country and for every kind of work on the Continent) divides the same interval in 100 units, and fixes the freezing-point of water as an arbitrary "zero", so that boiling-point becomes 100° C.

"Absolute zero" was unknown at the time these scales were introduced, or undoubtedly the Centigrade scale would have started there. As it is, absolute zero is − 273° C. or − 459° F.

Conversion Formulae. To convert a Centigrade reading to Fahrenheit, the formula is

$$F = \tfrac{9}{5}C + 32,$$

where F = the required number of Fahrenheit degrees,
and C = the given Centigrade reading.

In the other direction, and using the same symbols

$$C = \tfrac{5}{9}(F - 32).$$

The ordinary thermometer consists of a vacuum tube partially filled with mercury or coloured spirit, while the pyrometer (used for more intense degrees of heat) employs the expansion and contraction of a metal member, the movement being transmitted to a needle or indicator working on a dial.

Latent Heat. "Latent heat", for our purposes, is the heat absorbed by water in the process of conversion into steam, or by ice in the process of conversion into water. When heat is applied

to intensely cold ice, the ice goes on absorbing heat and rising in temperature at a uniform rate until 32° F. is reached, when 142 B.Th.U. of heat would be absorbed by the ice in thawing, for each pound of water formed.

In the same way, when heat is applied to water, the temperature of the water rises steadily until 212° F. is reached. At this point the temperature remains at a standstill until 966 B.Th.U. have been absorbed in the process of converting each pound of the water into steam.

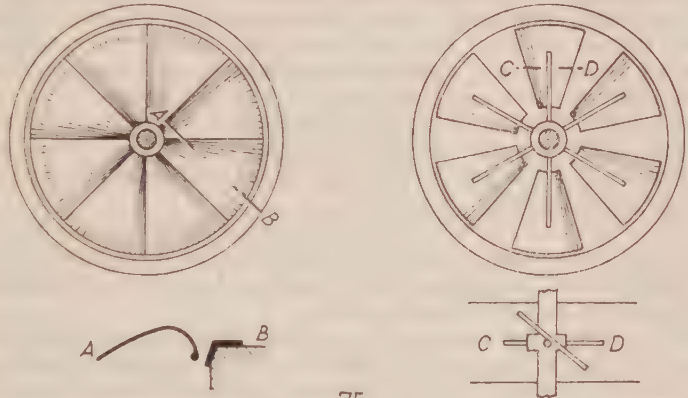
The real value of this quality is seen in low-pressure steam heating, where the steam, in condensing back into water, gives off its latent heat again.

Specific Heat. "Specific heat" is the capacity of a substance for absorbing heat, the specific heat of water being taken as the standard.

Thus, iron has only one-ninth of the specific heat of water, which means that whereas 1 lb. of water raised 1° F. absorbs 1 B.Th.U. of heat in the process, 1 lb. of iron raised 1° F. absorbs only 0·111 B.Th.U. of heat.

This makes water a very good medium for heating purposes, for it has a good capacity for absorbing heat and, after passing around the circuit of pipes to the various radiating surfaces, has a large amount of heat to give up.

Transfer of Heat. Three methods of transferring heat are made use of in heating schemes, namely, radiation, conduction and convection. "Radiation" is the transfer of heat by heat waves through the ether. In "Conduction" the transfer is caused by the vibration of the molecules of which the substance is composed being transferred to the molecules of a neighbouring body by physical contact, while "Convection" is the transfer of heat by the circulation of a fluid or gas. Convection is really one application of the law of gravity. The open fireplace furnishes a good example of radiant heat. From each particle of fuel, and from the fire-brick sides and back, the heat is radiated in straight lines. The rays diverge and affect objects at a greater distance to a less degree; the air is not warmed but the heat is radiated to individuals and objects, being re-radiated from the latter to a certain extent. Consider the phenomenon illustrated in Fig. 80. The black dot represents a particle of incandescent fuel and the diverging lines show the diverging rays of heat. At A is a small screen which receives all the heat from that particular particle of fuel. If A be removed, and a screen be placed at B, it will have to be of a larger size to receive the same total amount



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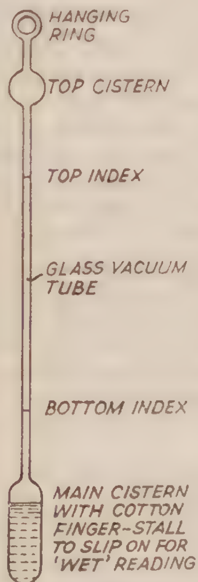
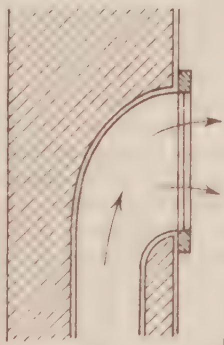


78. KATA THERMOMETER



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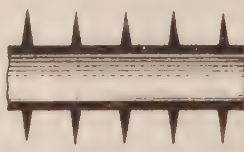

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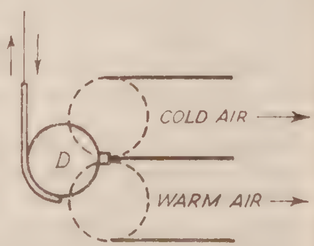

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of heat as would be received by A, therefore receiving less heat per unit of area. Similarly, if there be no screen at either A or B, a screen placed between the same rays at C would have still less heat per unit of area. Putting it another way, the heat decreases as the distance increases, and in a ratio of the square of the distance. Thus, compare a surface 1 square inch in area at a distance of 1 foot, with a similar surface at a distance of 10 feet. The latter will only receive one-hundredth of the heat that would be received by the surface 1 foot away.

Again, suppose a screen to be placed at C, there being none at A and B; if the small screen A be placed in the position shown, it will shut off all the radiant heat from C. A practical example of such a case is the use of a fire screen.

It is not strictly correct to say that with open fireplaces the room is entirely warmed by radiant heat. The walls, furniture, etc., become warmed by the radiated heat and warm the air in contact with them; this circulates around the room.

"Conduction" may be seen used indirectly in most heating schemes. The heat of the burning fuel is transferred (mainly by conduction) to the iron of the boiler, by conduction through the iron to the water inside. The water now illustrates heat transfer by "convection", for the warmed particles expand, become lighter and float upwards to the top of the boiler, being pushed up by the heavy cold water in the return pipe, and the circulation in the hot-water pipes thus begins. In the radiators the heat is transferred to the iron tubes or sections by conduction, thence to the air in contact, also by conduction, after which the air begins to circulate around the room, transferring the heat by convection.

It will be seen, then, that the fittings we call "radiators" have very little real radiating value and they would really be better described as "convectors". The relative amount of heat given off by radiation and convection into a room warmed by hot-water "radiators" depends on the circumstances, but it is easy to put the case to practical test by holding the hand 12 inches away from an average radiator, first at the side and then over the top.

Radiant heat, then, does not warm the air; this can only be done by bringing the air in contact with heated surfaces.

Materials which absorb heat readily just as readily part with it again. Iron fulfils the condition well and is cheap and is therefore used almost exclusively for pipes and radiators used in heating.

Modern Methods of Warming. Modern methods of warming

include both "Unit", "Central" and "District" heating systems, which, again, may be divided broadly into the following groups:

Unit Heating Schemes—using open grates, closed stoves, oil stoves, gas radiators, electric radiators.

Central Heating Schemes—including low-pressure hot-water pipes and radiators, high-pressure hot water, low-pressure steam pipes or radiators, high-pressure ditto and hot air heating—the latter frequently combined with air conditioning and ventilation as the "plenum system" already referred to.

District Heating Schemes. This term refers to arrangements whereby the heat is produced in an independent building and passed by pipes or ducts to the owners of as many houses, flats or buildings in the district as can be persuaded to take and pay for it in a manner rather similar to the Gas Boards with their gas or the Electricity Undertakings with their current.

This rough classification is by no means exhaustive, but it must be borne in mind that the central heating of large buildings is specialists' work, and the aim of this chapter is merely to indicate the general principles involved and perhaps to help the student and the man in general practice to select his system wisely, to choose the right firm to carry out the work for his client and, finally, check over the work on completion and see that his client has received a fair deal.

Those who intend to specialise will find numbers of treatises available, some devoted to the whole subject, others restricted to some single section of the work in all its technical details.

"Unit" and "Central" Schemes. Discussing "Unit" and "Central" heating schemes generally, it may be said that the unit scheme is simpler, easier to manage by the novice, or by the caretaker without technical knowledge, is cheaper to install and is more suitable for use in buildings which will need to be warmed intermittently and one room at a time.

Central heating schemes usually need greater capital outlay in the first place, are more complicated, need rather more skill in management (in some cases an attendant with technical knowledge is essential to satisfactory running) and they are more suitable for buildings which will need to be warmed all day and every day in every part.

Of course, a large building heated by low-pressure hot-water radiators can have certain radiators, or even certain sections of the building, cut right out by control valves, but the general truth remains that, for real economy of running, a central heating

scheme needs to be used for the whole of the building continuously. For this reason, comparative tables of fuel cost, such as are often put forward by the manufacturers of different classes of heating apparatus, need to be judged with a good deal of circumspection.

Relative Costs. As an example, the following is quoted. Relative cost of fuel needed to produce 1 therm (100,000 B.Th.U.) in

Coke-fired boilers for low-pressure radiator system	= 8d.
Closed stoves burning coke or anthracite	= 1s.
Open grates burning bituminous coal at £8 per ton	= 2s.
Gas fires burning gas at 1s. 11d. per therm	= 1s. 11d.
Oil heaters burning paraffin at 2s. 1d. per gallon	= 3s. 1½d.
Electric radiators consuming current at 1½d. a unit	= 3s. 9d.

Even when similar comparative costs are given by such impartial research workers as Dr. Margaret Fishenden of the Fuel Research Board, allowance still has to be made for possible variations in the cost and quality of fuel, in the stoking and, more important still, in the conditions of use. No price is given for the coke and anthracite employed in the above example, and it may therefore be assumed that prices comparable with coal at £8 per ton were being paid.

Oil-fired boilers would probably cost a figure about midway between coke-fired boilers and closed stoves. It requires 29¼ B.T.U. (Board of Trade Units) of electricity to produce 1 therm (100,000 B.Th.U.) of heat.

Measurement of Gas. Coal gas is usually measured by meters recording thousands of cubic feet, but the charge (by statute) is by the "therm" or 100,000 B.Th.U. according to the declared calorific value of the gas. This varies with the Gas Board concerned and with the date and the general policy of production. At the present date a calorific value in common use is about 500 B.Th.U. per cubic foot which, at 1s. 11d. per therm, would give a charge (according to the old rating of thousands of cubic feet) of:

$$\frac{1000 \times 500 \times 1\cdot 9}{100{,}000} \text{ shillings}$$

$$= 9\text{s. } 7\text{d. per } 1000 \text{ cubic feet.}$$

To convert the meter reading in "thousands" into "therms" multiply the reading in thousands (say 5) by the calorific value

in B. Th.U. (say 500) and divide by 100,000. Thus, 5000 cubic feet at 500 calorific value

$$= \frac{5000 \times 500}{100,000} = 25 \text{ therms.}$$

District Heating. District heating offers many advantages from the national economy point of view and not a few to the local community and the individual consumer—thus:

National Advantages

1. Fuel can be consumed more economically in a central heat production plant than in a small private boiler or an open grate.
2. The large plant can be designed to burn a poorer grade of fuel.
3. Coal stocks can be conserved.
4. Plant could be more readily adapted to use new forms of heating energy (such as atomic power) than the small private plant.

Local Advantage.

1. Much of the smoke and fog nuisance, quite a lot of which is said to be produced by our wasteful habits of burning bituminous coal in open grates, would be reduced.
2. The rapidly dwindling stock of building land in our urban areas would, to a small extent, be conserved, since a central district heating station takes less space than scores or hundreds of smaller boiler houses—though admittedly this advantage is likely to be felt very gradually, as rebuilding was carried out making full use of the space previously occupied in this way.

Advantages to the Individual Consumer.

1. Greater comfort in living conditions.
2. Hot water on tap in any quantity day and night.
3. Warmth all over the house or building day and night, with complete control.
4. Saving in labour.
5. Saving in ash and dust.
6. Saving in decoration.

The disadvantages are mainly a matter of exploitation of the possibilities:

1. The capital outlay in buildings, plant and distribution mains is high and the task of persuading consumers (already provided with reasonably satisfactory hot-water and warming facilities) to accept the district supplies in economic numbers is likely to be wellnigh insuperable except where big landlords or local authorities are opening up new estates with these facilities incorporated in the scheme.

2. The cost of the facilities offered—while very low for the advantages of constant hot water and all-over-the-home warmth, day and night—will certainly be higher than the cost of an occasional kettle of hot water and a single living room warmed for a few hours a day by open grate or kitchen fire which so many small householders "enjoy" at present. There is no doubt at all that the householder would get very good value for money—if he can afford the luxury. Students interested in further details of District Heating might well obtain the report on District Heating by the Heating and Ventilation Committee of the Building Research Board, vols. 1–6 at 17s. 6d. from H.M.S.O., or articles on specific District Heating Schemes in various professional journals.

Development of the Open Grate. Dealing in rotation with the various available methods of warming, we find mention of iron grates for burning coal occurs in inventories of the early sixteenth century, and at the end of that century we know that the depth and width of the hearth recess was much reduced and the mouth of the flue contracted. An Italian architect, Scammozzi, writing at that time, also says that, in England, a door of iron is used to partly close the flue after the fire is well lighted, this being the first mention of the register plate.

About 1624 a French architect, Savot, further reduced the height and width of the fireplace opening and introduced the iron back and covings, together with the perforated base plate of the ordinary grate still in use. About 1738 came the use of fixed canopies, adjustable registers, and the insulation of the grate by means of air spaces behind it. In the same century the well-known Bath fireplace was in vogue, consisting of a hobbed grate with an iron plate front, having an arched opening in it. It had great draught-creating powers, carrying off all the air in the vicinity. An old English writer, in commenting on it, says, "whoever, impelled by the merciless severity of the frost, comes near the grate, will find his front fried and his rear frozen".

At the beginning of the nineteenth century, Count Rumford, a versatile American, at various times shop-boy, soldier, diplomatist, financier, scientist, and founder of the Royal Institution in our own country, did more to improve the fireplace than anyone up to that time. He it was who brought the fire grate forward, the mantel lower, emphasised the importance of forming a "throat" to the flue, and introduced the diverging sides and covings to obtain greater radiation of the heat into the room. He pointed out that the bars should not be too far apart, ensuring brightness

of the exposed surface of the fuel and increasing the radiation of the heat, and that dull, rough, iron covings were better radiators of heat than polished surfaces.

Dr. Teale's Experiments. Later in the nineteenth century, valuable experimental work was done in connection with the improvement of fireplaces by Dr. Teale, F.R.S., who embodied his conclusions in a paper read before the Royal Institution in 1886, on "The Economy of Fuel in House Fires". The chief conclusion obtained by Dr. Teale was that slow and efficient combustion depends on there being no current of air up through the grate, and he accordingly introduced what is known as the economiser, shutting in the space below the grate. He also laid down a series of rules for the design of fireplaces, the principal of which are:

1. Use as little iron as possible, making both back and sides of fire-brick.

2. The fire-brick back should lean over the fire; and

3. The greatest efficiency is obtained from the covings when they are inclined at an angle of 60° to one another.

To these might be added the need for a controlled draught, a throated flue and a good chimney capped by a clean-cut pot, clear of obstructions and free from the blanketing effect of high buildings or trees in the vicinity, which might cause a back pressure or down draught.

The Sunk or Well Type. Later investigators have held that it is important that the air should not pass through the face of the fire, and so have designed fireplaces of what is known as the sunk type with raised hearths in front and ventilating fenders communicating with a hot-air chamber below the grating at the base of the fire, practically the whole thing being formed of fire-brick. In some examples the base of the grate is formed with reinforced fireclay bars to prevent the absorption of heat by the iron.

Other experts hold that there is no necessity to supply air to the lower side of the fire and that a grated base with an ash-pit under is a superfluity. It has been fairly well demonstrated that a good fire can be obtained without any air supply other than that passing over the top of the fire; that more perfect combustion is thereby attained with economy of fuel; and that much less draught is caused in the room owing to the demand for air being far less than in the older types of grate.

It should be pointed out, however, that, in almost all types, ashes will accumulate and require removal. The grated base allows for the removal of the ashes without letting out the fire, which is a point not to be overlooked in the case of a sick-room

where a fire is constantly required, while another advantage is that the fire, when newly ignited, can be "drawn up" more quickly if air is allowed to pass through the burning fuel. As soon as the fire has burnt up sufficiently, the damper (if one is provided) can be closed and the fuel will then burn more slowly with the air supply from the top only.

It should be noted, in passing, that logs burn best in their own ash, so they should be burnt on a flat hearth or in one of the sunk type, but coal does not burn so well in these conditions, and better control is obtained if a fretted stool is used through which the ash can fall for easy removal. The air supply can then pass under or over the fuel according to the rate of burning desired.

Care must be taken that open grates of this type are not placed on a hearth with timbers under or in too close proximity.

Fig. 81 shows a "slow-combustion" grate of the sunk type. The fireclay base is in three pieces, the central portion being sunk to form a well; the upper side of the base is at or about floor level. The upper part of the grate is of fireclay, moulded in one piece, with its back leaning forward to reflect heat towards the floor and with its sides diverging outwards to reflect heat into the room.

A modification of this has a flat hearth with a loose and movable stool, standing on three or four dwarf feet, sometimes (in the larger sizes) provided with wheels. This gives excellent control of fuel consumption, as air can be admitted through the bottom of the stool when the fire is first lighted whilst, when it is desired to slow down the consumption, the fret can be pushed in to stop the through draught and the fuel will burn more slowly, as in the case of the sunk type.

The Coal Utilisation Council. Some mention must be made here of the Coal Utilisation Council whose signs, "Authorised Solid Fuel Appliance Service" and "Coal Merchants' Diploma Service" (in a circle with black-and-white diamonds over it), are to be seen in practically every town in the country. The council has not only made a careful study of the use of coal and its derivations and made their knowledge available to the public, but has also instituted a training service enabling the staff of shops and stores marketing solid fuel appliances to learn the principles of design and construction of grates and stoves for different purposes. It has done the same for the staffs of coal merchants so that they may be able to advise the public as to the best fittings to purchase and the most suitable fuel to burn in them.

Continuous Burning Open Grates. The main points they emphasise in the design of open grates are the close control of air

supply, and the easy removal of ash from the firebars into an ash tray, where it may be removed by the housewife without scattering dust about the room.

The council does not issue a standard specification like the British Standards Institution, but manufacturers of these appliances can submit their designs and models for approval by the council and if found satisfactory they can be put on the market with the seal of the council's approval. Most of the open grates sponsored by them are vitreous enamelled for easy cleaning, bolted down to the hearth and sealed up with fire-cement everywhere except where the air supply is to flow by design. The lower part of the front (taking the place of the sliding "feet" in older models) is machine ground where it fits against the body of the stove, the air supply being controlled (often foot-operated) either by a sliding shutter, a hinged trapdoor or screw-controlled circular inlet. Other sponsored models are "self-contained" so that they can, if desired, be moved from one room to another, without the bolting down or the need for the fire-cement sealing process. Most of the bolted-down models can be provided with gas ignition if desired and some are designed to work with a back boiler to replace or to augment the range boiler or the independent boiler in small houses. Nearly all open grates of this type are designed to burn with a bright fire all day and with a slowly-burning fire at night by nearly closing the air control and loading up the fire with small coal. An extra inch or two of front is usually added for night burning as a safeguard and to hold the extra fuel for long continuous burning without attention.

Convection Types of Open Grate. Models which include the Galton System of air warming (either for circulating warm air in the same room or for background warmth in the room or rooms above) are also sponsored by the Council—generally known now as "Convection" models.

Reference should also be made to the "Plumbing Unit" described in Chapter VII which also makes use of the Galton idea.

Closed and Openable Stoves. "Closed" and "openable" stoves to burn anthracite or semi-anthracite also come under review. These are either of "built-in" type or are "freestanding". The freestanding model is not really portable, but stands on the hearth in front of the fireplace opening, with a short length of stove-pipe at the back taken through an iron or asbestos-cement panel which fills and seals the fireplace opening and prevents uncontrolled air currents passing.

The student is advised to compare the different makes and

types of open fire and closed stove which he will find in his own and his friends' houses and also in the showrooms of builders' merchants and others. There is considerable prejudice, in some quarters, against the use of closed stoves in this country, as people want to see the fire. The older forms were apt to get very hot, and they roasted and burned the organic matters in the air, giving off unpleasant odours. They were liable to decompose the air and they certainly deprived it of much of its moisture. The average type of closed stove gives less help to ventilation than the open grate. The following extract from the works of an old writer, Jeremy Bentham, is an amusing commentary on the manners of his time: "A bad smell often arises in consequence of people spitting on the stove to try if it be hot, but his nasty, unmannerly practice should be reckoned to the discredit of the spitter and not as an objection to the spitee."

With closed stoves there is some risk of the escape of carbon monoxide, so all the joints shall be carefully made, particularly in the "freestanding" models, where the short lengths of flue emerges at the back and passes through the wall or sealing panel into the brick flue.

Both the freestanding and built-in models are usually lined with fire-brick and cased with vitreous-enamelled iron, having inlet and outlet air-frets, so that the air of the room can enter the warm air chambers, emerge at the upper openings and circulate around the room by convection.

To make the appearance more cheerful, mica panels are usually put in the front fire door or doors. In the "closed" type there will be only one such door, hinged on one side only, but in the "openable" type, there will be two smaller doors opening out flat, when of course the fuel should be changed to a more free-burning type such as Coalite or semi-anthracite or even to ordinary house coal.

When closed and used with anthracite, these stoves are very labour-saving as, with care, stoking can be done about twice in the 24 hours and ashes can be raked out by an outside handle, without getting dust out into the room. Stoves of this type are usually very economical.

Air-heating Stoves. The ventilation provided by stoves of the type just described is not so good as with the open grate, but this disadvantage is sometimes offset by bringing a fresh air conduit to the base of the stove as shown in the next example, Fig. 84, which gives a diagrammatic section of the "Musgrave" stove, which is closed in. The sketch shows it with a back outlet for

smoke, but the descending flue can be used carried under the floor to the nearest wall capable of carrying a flue. The stove is lined with fire-brick, shown by hatched lines, and the iron work is shown throughout by thick lines, the dotted lines indicating grating outlets for warm air.

Oil Heaters. Oil stoves for heating the houses and other buildings do not need very serious consideration, except for use right away from such public services as gas and electricity supply companies can give. Oil heaters usually burn refined paraffin—some with a wick, others wickless.

In some the heat is radiated by a parabolic reflector. In others it is distributed by convection, the air passing through and over the heated surface of the container, or, again, the flame may be placed under a tiny boiler at the base of a hot-water or steam radiator.

Oil heaters are economical in theory, since the whole of the heat produced is passed out into the room. They are usually very portable and are sometimes used for warming up rooms needed only occasionally, even in houses having all the advantages of the town. They have the disadvantage, however, that all the by-products of combustion pass into the air of the room. There is a good deal of trouble entailed in filling, cleaning, trimming, etc., rather more risk of fire than with most other methods of warming, and very unpleasant effects if the cleaning is neglected or the adjustment of the flame is mismanaged. Refined paraffin is expensive as a source of heat, so that the oil heater's claim to economy is more apparent than real and can be substantiated only in cases where warmth for short periods at a time is all that is desired.

Gas Fires. The gas radiator, on the other hand, is used a great deal for buildings where individual rooms are required to be warmed for short periods and they are then very convenient. Most of the heat produced is available to the occupants of the room, since the heat is passed out mainly by radiation, and far less heat passes up the flue than would be the case with a coal fire. Occasionally "portable" gas fires are used without a flue, but this is most unwise, since all the by-products of combustion pass into the air of the room. This results in unhealthy conditions in any case, while, if there should happen to be any misadjustment of the air supply to the burners, the incomplete combustion will lead to the formation of carbon monoxide—a most dangerous gas which has often caused fatal accidents. Even when the amount of monoxide formed is small, this gas is still dangerous, as it is a cumulative poison.

Ordinary coal gas, as supplied by public authorities, is produced by the destructive distillation of coal, free from access to air, the resulting product being purified by various processes. It is mixed with air and burnt in properly constructed burners.

The typical gas radiator consists of a row of Bunsen burners under "radiants" of skeleton fireclay formation, dotted with slender points which rapidly become incandescent, and radiate the heat into the room. The most modern types are provided with a small dry battery and an ignition coil operated by the gas tap. This makes lighting as simple as the switching on of an electric radiator, and it is likely that the user will switch the fire off when leaving the room unoccupied, even if only for a few minutes, thus tending to economy, apart from the convenience. A spring against which the tap presses, when the gas is turned on, automatically breaks the electric current as soon as the fire is alight, and so prevents wastage. It is said that one dry battery, costing a few pence, is enough to last through the entire winter season, so that a renewal once a year is sufficient.

Parabolic or bowl type reflectors are sometimes used for small portable gas radiators, but as this form has no flue, their use cannot be recommended.

Gas-fired Water and Steam Radiators. Water- or steam-operated gas "radiators" of the sort mentioned under oil heaters are also in use, but should be used only when the ventilation is extra good, owing to the absence of flues. Gas fires are very popular for rooms in which a fire is not constantly required, such as bedrooms. If in continuous use they are less economical than the coal fire, but for occasional use they have the advantage that they can be brought to their full heating power in a few seconds and that the expense of the fuel can be shut off immediately the fire becomes unnecessary. A good type of gas fire should be formed largely of fire-brick and asbestos, as little iron as possible being used in its construction. If the gas fire communicates with a flue, as it should do, it materially assists the ventilation of the room by inducing a current of air across the floor towards the fire.

Ventilating Gas Fires. Certain forms of gas fire are constructed with a double flue, with the object of inducing an extra current of air to flow from the room, thus aiding the ventilation; but this is bound to result in some loss of efficiency if the flue is made larger than is needed for carrying off the by-products, while, if there is no increase in size, it can help very little more than the usual flue outlet would do. Oil and gas used as fuel in central heating schemes will be dealt with later.

Calor Gas. In country districts in which there is no piped supply of coal gas a useful substitute is Calor Gas, which is widely used throughout the British Isles for cookers, gas fires, radiators, etc. It is a saturated hydrocarbon called butane, with a calorific value of about 3200 B.Th.U. per cu. foot, a figure far in excess of that of coal gas (which is usually about 500 B.Th.U. per cu. foot); at atmospheric pressure it is a true gas, but is liquid at a pressure of 28 lb. per sq. inch.

It is supplied by the Calor Gas Distributing Company in steel cylinders which contain 32 lb. or 83 lb. of the liquid under pressure. The 32 lb. cylinder will yield 210 cu. feet of the gas when released from the cylinder.

The consumer must obtain two cylinders, so that one may be available while the other is being collected and replaced by the Company's local agents. Each 32 lb. replacement cylinder costs about 25 shillings, so that the cost of 1 cu. foot of this gas, ready for burning, is about 1¼d. Each cubic foot needs to be supplied at the burners with 30 cu. feet of air for proper combustion. This is a much larger proportion of air than is used with coal gas, so that fires and radiators which have been designed for the one cannot be used for the other without adaptation, and it is far better to install appliances which have been designed for the purpose.

The cylinders should be kept indoors, because the pressure will change if temperature varies; the gas is delivered from the cylinder to the appliances usually by copper tubes ¼ inch external diameter, though flexible connections can be supplied for portable fittings. The gas being rather heavier than air, some care is needed if any installation is placed below ground level.

The cost of the gas, as a means of warming a house, appears to be about the same as that of electricity at a little more than a penny a unit; this is a much lower figure than the price at which electricity is obtainable in country districts on a flat rate, or the equivalent price where a two-part tariff scheme is in operation.

Electricity. Electricity for warming provides the most sanitary and the most convenient heating unit, and all the heat produced is available for warming the air and the occupants. Unfortunately, even with current at ½d. or 1d. a unit, it forms a most expensive method of warming buildings, except when required for occasional or irregular use for short periods at a time.

Radiant Electric Heaters. Not the least of its advantages is the convenience and cheapness of installing electrical heating apparatus in an existing building and the fact that no fuel store is necessary. Electrically heated boilers for central heating can

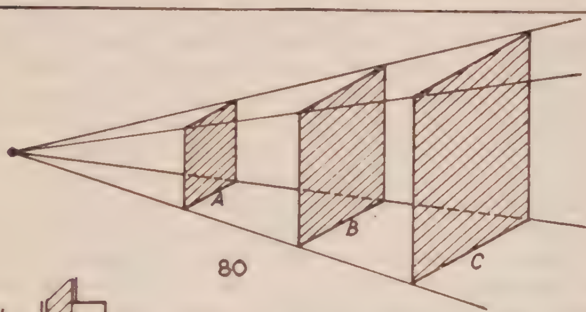
be used, but they are very unusual, and electric unit heaters lend themselves to such complete control, either by hand or automatically by thermostat, that they are nearly always installed in preference.

The methods of application vary, but they may be divided into two groups—those in which the heat is mainly radiant and those which warm the air by convection.

Early electric radiators consisted merely of large electric lamps or bulbs in a metal frame or casing. The filament was usually less incandescent than when used for lighting, but a certain amount of light was emitted. The early forms were not very efficient and, even with the improved forms of gas-filled bulbs, such heaters were usually restricted to small radiators designed for decorative effect as much as for heating efficiency. Electric radiators with exposed filaments of high-resistance wire, coiled round a bar of fireclay or asbestos cement, are perhaps the most popular form for small buildings. The full heat is felt as soon as the filament has become heated to a dull red and the radiator "bar" has become hot. Fig. 82 illustrates a very common form. They may be built into a tiled or other "fireplace" surround, or made in portable type. If the latter, it is common practice to arrange the switches in such a way that the switch plug, from which the flex is taken, controls one of the radiator bars, while the remaining bars are controlled by a switch or switches on the radiator itself. Sometimes a "flicker fire" effect is added, in the form of coloured glass made to imitate burning logs or coal, the flicker being produced by a small bulb with a tiny propeller above, which is rotated by the convection currents and which interrupts the light shining through the "coal", the effect often being very realistic and probably, in many cases, helping the effect of warmth by the power of suggestion.

Modern taste tends towards severity in design, and plain metal tubes holding a parabolic or bowl-shaped reflector, with the heating element in the focus of the reflector, are displacing the more ornate forms in public favour. Figs. 83 and 82 illustrate common designs. The first type is frequently set (in vertical form) in small recesses on either side of the tiled surround of an ordinary open grate burning bituminous coal. They then form a very useful auxiliary source of heat for cool evenings in early autumn or late spring, when the day temperatures do not call for the use of a fire, or when a room is required for a short period only.

Electric Convector Heaters. Electric tubular heaters, batteries of gilled tubes and metal panels with electrically insulated electric



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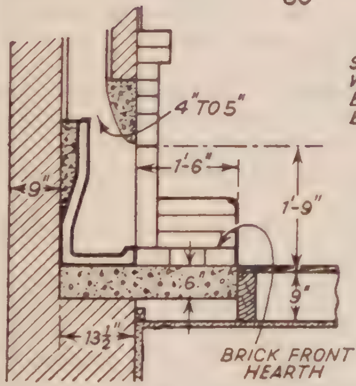

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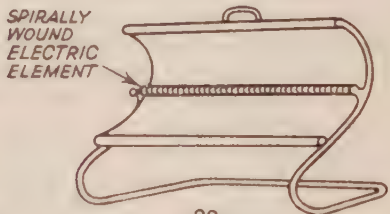
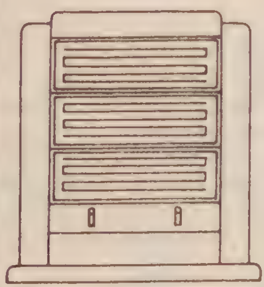


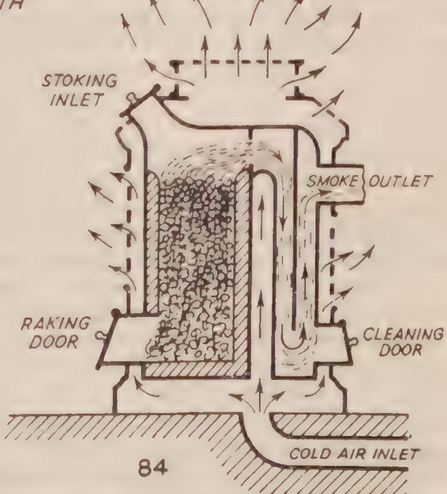
82

REFLECTING TYPE OF ELECTRIC HEATER.
1 UNIT SIZE (1 KILOWATT).



83

3-BAR RADIANT ELECTRIC
HEATER CONSUMING 3 UNITS
OF CURRENT PER HOUR



84

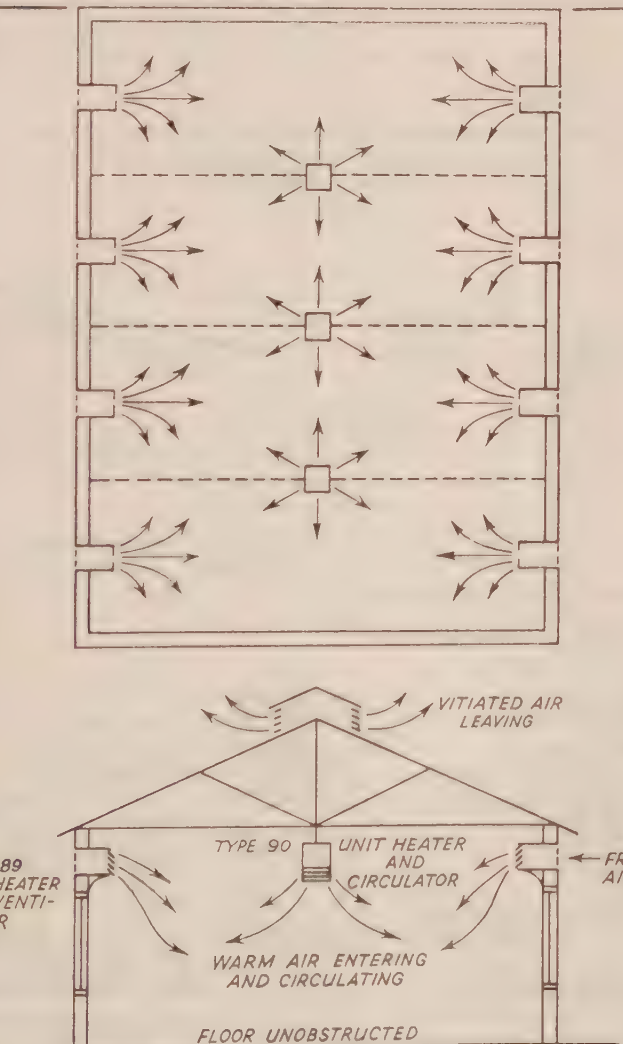
elements, in ducts or cavities in their interior, are some of the forms employed in the "convector" class. Most of the heat produced is passed into the air by conduction and circulated around the room by convection. The tubular form (illustrated in Fig. 86) may be fixed in a linen cupboard, under a window seat, or around the skirting of a room. In order that a large area of mild temperature may be used, the tubes are generally loaded with about 60 or 80 watts per foot run and, as a rough guide, it may be taken that 1000 watts (or 1 kilowatt) is about the heating requirement of a room containing 1000 cubic feet of air space. Too close adherence must not be kept to any such rule of thumb, however, for obviously the heat losses cannot be gauged purely by the cubic capacity of the apartment to be warmed.

Electric (Convection) Cabinet Heaters. The gilled tubes are more often employed as air heaters in a metal cabinet or casing such as is illustrated in Fig. 88. These may be fixed by an outer wall or under a window, in just such positions as would be selected for a hot-water radiator.

Electric "Unit" Heaters. Another application of the gilled-tube type of radiator is that illustrated in Figs. 89 and 90. In Fig. 89 an electric fan blows fresh air from a ventilating inlet in an outer wall, over the surface of gilled electrically heated tubes, to be deflected downwards on to the occupants of the room by adjustable louvres on the front of the casing. This is a reasonably efficient contrivance for a small room, but, as the warm air tends to rise directly it gets out of reach of the fan, it is not easy to ensure that every occupant of a large room will get a fair share of the warm air.

Unit heaters of this type, or as shown in Fig. 90 (without ventilation inlet, and suitable for suspension from the ceiling or a roof tie-rod) may be used in conjunction to warm and ventilate a workshop or similar room as in Fig. 85. The fan and the adjustable deflector vanes or louvres direct the warmed fresh air downwards towards the workers until overcome by the tendency of warm air to rise. At this point units of the type shown in Fig. 90 may be placed, suspended at about 8 feet from the floor to warm and recirculate the air in the neighbourhood of the benches in the centre of the floor.

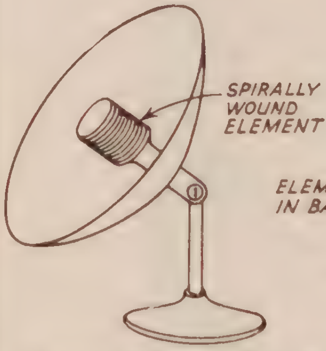
Fig. 91 shows an electric unit heater in which the gilled heating tubes are arranged in a cabinet with a grating in the top, under which an electric fan blows the air downwards through the heating batteries, to be deflected sideways when it reaches the floor. The use of these two contrivances is not restricted to electric



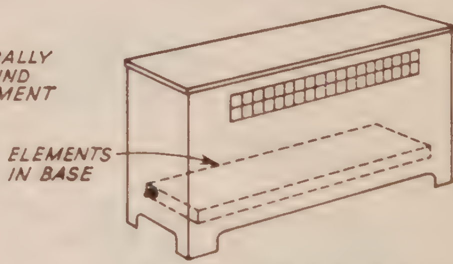
DIAGRAMMATIC PLAN AND SECTION OF WORKSHOP WARMED AND VENTILATED BY UNIT HEATERS TYPE 89 (IN OUTER WALLS) AND TYPE 90 (NON-VENTILATING) AND SUSPENDED FROM TIE RODS

85

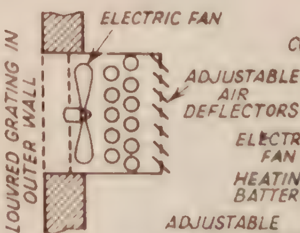
ELECTRIC (CONVECTION) HEATER, TUBULAR TYPE
CONSUMPTION 60 TO 80 WATTS PER FOOT
(VARIOUS LENGTHS)
86



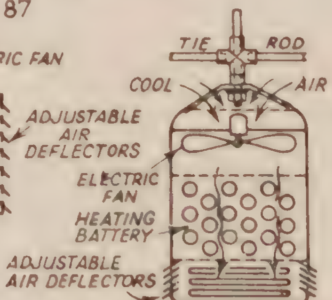
RADIANT ELECTRIC HEATER,
BOWL TYPE
½ UNIT SIZE (500 WATTS)
87



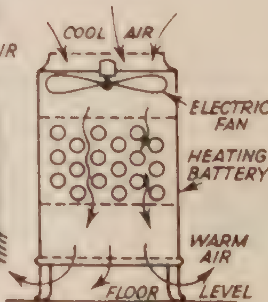
ELECTRIC (CONVECTION)
CABINET HEATER
88



ELECTRICALLY-HEATED
PLENUM "UNIT" VENTI-
LATOR. (SECTION)
(SUITABLE ALSO FOR USE
WITH HOT WATER OR
STEAM PIPES)
89



UNIT AIR
HEATER,
TIE ROD
MODEL
90

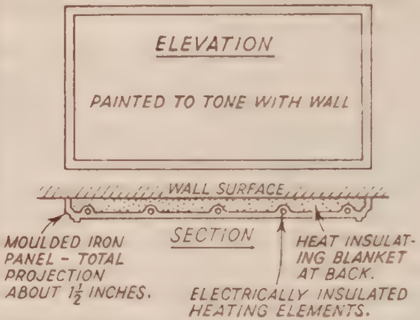


UNIT AIR HEATER
(SECTION)
(FOR ELECTRIC, STEAM
OR H.W. HEATING)
FLOOR MODEL
91

heating, and the batteries of gilled pipes may, of course, be heated by hot water or steam if found more convenient.

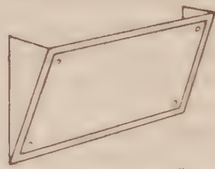
Electric Panel Heaters. Electrically heated panels (shown in Figs. 92 and 93) have the advantage of taking very little space in the room. The type shown in Fig. 92 is perhaps the most suitable for a dwelling-house, while Fig. 93 illustrates a form suitable for an office or workroom where appearance is unimportant. These panels, especially those of the first type, are generally maintained at a comparatively low temperature, so that proportionally more of the heat shall be passed out by radiation and less by conduction. This may sound somewhat contradictory, since it is usual to connect luminous heaters with radiant heat and non-luminous ones such as hot-water pipes with convected heat. It must be borne in mind, however, that when heat is passed from the hot water to the iron of the pipes or radiators and thence to the air by conduction, the speed of conduction is accelerated by increasing the difference in temperature of the water and air respectively. By lowering the temperature of the panel less heat will be passed by conduction into the air, and the radiation, which is unaffected, will then occupy a larger proportion of the total heat emission.

Electrically Heated Hot Water Radiators. One other form of electrical convector should be mentioned, namely that in which a small cylinder of water, containing an electric immersion heater, is surmounted by the conventional form of hot-water radiator. The tubes or sections of the radiator in some cases are filled to the top with water through a filling plug, and the hot water in the miniature boiler or cylinder, at the base, then circulates through the sections by convection. The water takes rather a long time to warm up. The time "lag" between switching on the current and the emission of the heat into the room may be shortened by filling only the cylinder with water, which then boils quickly and the steam rises up into the radiator sections. Both types are in fairly common use and may be preferred to exposed luminous radiators where there is much inflammable material in close proximity to the radiators. The radiator is sometimes filled with a **special grade of oil** instead of water. One of the great advantages of electrical heating is the ease with which automatic control can be applied by thermostat. In some cases a time switch is employed to set the heating apparatus going at a given hour, a thermostat maintains the temperature of either water or air during the day and the time switch turns off the current again when it is no longer needed, while, as explained in the chapter on ventilation, it is possible to discriminate between the control of



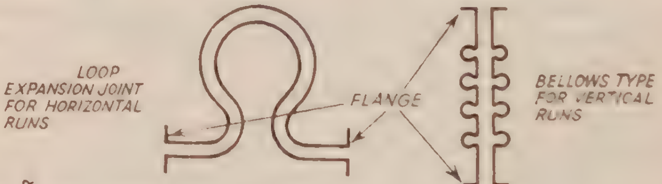
"LOW TEMPERATURE" ELECTRIC PANEL HEATER
(LOADING ABOUT 70 WATTS PER SQUARE FOOT)

92



"HIGH TEMPERATURE" ELECTRIC PANEL HEATER
(CAN BE SUSPENDED FROM CEILING OR FIXED AT AN ANGLE TO WALL BRACKETS TO DIRECT THEIR HEAT AT THE RECIPIENTS)
(LOADING ABOUT 500 WATTS PER SQUARE FOOT)

93



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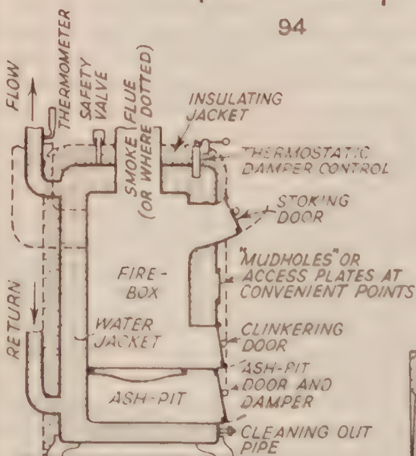
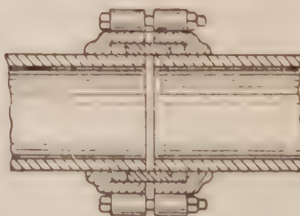


"ONE PIECE" DOMESTIC BOILER
(SMALL SIZES HAVE WATERWAY BACK AND SIDES ONLY)

96



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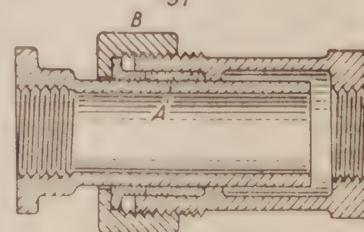


98

radiant and convected heat by the use of an eupatheostat and a "relay", should this be thought desirable.

Thermostatic Control. It is true that most forms of central heating and some forms of unit heating can be controlled thermostatically, but the "all-electric" is particularly adapted to this type of control.

Oil Heat Storage. Sometimes electricity is obtainable at very cheap rates during the night, and in this case it may be worth while, in large blocks of buildings, to install an oil thermal storage plant. This is contrived by placing electric immersion heaters in a heavily insulated cylinder of heavy oil, of a grade which will not boil or vaporise until a temperature of about 500° F. is reached. A time switch ensures the current being used only during the "cheap" hours, while the intensely hot oil can then be used at any time of day or night to circulate through the coils of a calorifier, which is simply an indirect boiler and can be used for raising steam or hot water as required.

Low- and High-pressure Water Systems. The installation of central heating systems for large buildings is generally undertaken by specialists, and only a general idea of the construction and arrangement of such systems and the principles upon which they operate will be given in this chapter.

For the warming of buildings by hot water there are two main systems available, the low pressure and high pressure respectively. In the former a system of circulation is set up, the water being heated in a boiler, supplied by a cold-water cistern placed in a position above the highest point to be supplied with hot water. The water becomes lighter as its temperature is increased, and rises, being replaced by the heavier cold water. The water expands to the extent of $\frac{1}{24}$ to $\frac{1}{25}$ of its bulk in the process of heating, and provision must be made to permit of this expansion.

In the high-pressure system the arrangement is somewhat similar, but differs in that the whole system of pipes is sealed, whereas in the low-pressure system there is a free communication with the atmosphere. The effect of sealing the system is that a much higher temperature can be obtained.

Low-pressure Hot-water Systems. The low-pressure system is largely used and will be dealt with first. Its advantages are that it is economical both in first cost and maintenance, gives an agreeably mild heat, and if well arranged tends to prevent draughts. The system is a much older one than the high pressure, having been introduced about the beginning of the eighteenth century by a Norwegian for the purpose of warming his greenhouse. It was

developed in France for incubator work and was introduced into England by a Frenchman, named Bonnemain, for domestic warming.

Low-pressure Boilers. There are many varieties of boiler, some set in brickwork and some quite independent, examples being shown in Figs. 96, 105 and 106. Of the latter, some are practically in one piece, while others are built up in sections, either vertically or horizontally, being known as sectional boilers. The independent boiler is rapidly superseding the older, brick-enclosed type, and the sectional form gives a splendid provision for readily increasing the size of the boiler without trouble. Further, a sectional boiler is more portable, the sections being capable of passing through any ordinary doorway. Boilers are made of cast-iron, wrought-iron, steel, and copper. Cast-iron is largely used, on the ground that there is less corrosion than with wrought. A boiler should not be too high, or it will restrict the fall available for the pipes; its flues should be readily accessible for cleaning. Its efficiency will depend on many factors, the principal of which are, the ratio of fire grate area to the boiler surface, its size in relation to the system as a whole, the size and height of the chimney, the regulation of the draught, the rate of firing, and the condition of the flues. By boiler surface in this connection one means the surface in contact with water. All boilers should have safety valves.

Water Tube Boilers. Some of the larger domestic boilers have the boiler surface made larger by the use of water tubes placed across the firebox in the upper part from back to front or from side to side, while boilers for large buildings are sometimes constructed entirely of water tubes.

Insulation of Boilers. All boilers (except small ones intended to warm the room in which they are situated, as well as the water they contain) should be "lagged" or insulated to prevent waste of heat. The insulating material is generally asbestos mixed with water and a cementing material applied to the outside casing.

For pipes, the insulating compound can be made up in sections and fitted after the insulation is complete.

A very neat insulation—especially for sectional boilers—consists of a sheet steel casing with a narrow cavity between it and the boiler walls. Some makers leave this cavity air-filled, which is seldom satisfactory, as it is difficult to make the jacket airtight, and a current of air will circulate. It is better therefore to pack it lightly with shredded asbestos, slag wool or some other insulating material.

The metal casing is a great advantage, as it is very difficult to obtain a neat finish with the usual insulating materials.

Fuel for Boilers. The fuel used in boilers for central heating includes coke, Welsh steam coal or semi-anthracite, anthracite, gas, crude oil and (not exactly a fuel but certainly a source of heat) electric immersion heaters. Of these, coke usually gives the greatest quantity of heat for a given outlay, but it is bulky and a large coke store is needed. There is also more labour in stoking than with other fuels. Steam coal and anthracite are rather more costly, but require less storage space. Gas and crude oil lend themselves very well to automatic or thermostatic control and very little oversight is needed. Gas, of course, needs no storage, while the use of fuel oil gives great economy of storage space, and the tank can, if necessary, be in some otherwise unused corner right away from the boilerhouse. Neither, however, is a cheap source of heat. Electricity, doubtless, is the most convenient source of heat for a boiler, but the cost makes it quite prohibitive for general use in this manner.

Pipes for Low-pressure Work. The pipes used in heating work are usually of either cast iron, wrought iron or copper. Their expansion and contraction under changes of temperature is a matter which may have to be reckoned with. For the warming of a small house or building, the pipe runs are usually interrupted by bends at fairly close intervals, while the pipes themselves are seldom more than 1½ inches or 2 inches in diameter, so that there is no need to make special provision for their expansion and contraction.

Allowance for Expansion. With long straight lengths of large-diameter pipe, however, such as might be necessary in a bigger scheme, special provision for expansion must be made and expansion joints are largely used. For long lengths of small-bore pipe —say up to 2 inches internal diameter—it is better to put an expansion bend in the form of a loop (Fig. 94). This should be of copper, as it is much less rigid in nature than iron. The bend should lie horizontally or it will form a dip or trap and so obstruct the circulation of the water. If an expansion joint is needed in long straight vertical runs, a bellows type of expansion joint in proved steel or copper may be used. In both cases, they should be connected by flanges, so that they can be removed and replaced if necessary (Figs. 94 and 95).

Jointing Hot-water Pipes. There are various methods of jointing the pipes. Those of wrought iron are generally jointed by means of screw threads only. Although some of the old systems

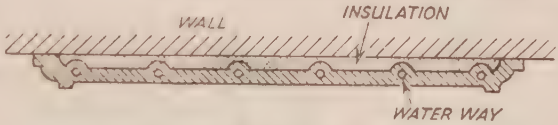
in copper employed threaded pipes, modern practice is to install light-gauge copper tubing jointed by either compression joints, brazed flange joints, capillary soldered joints, or bronze welding. Examples of joints used with drawn copper tubes will be found in Chapter VII. Cast-iron pipes are either socketed or flanged. In the former case, the joint between the spigot (or plain end) and the socket may be made in various ways, as follows: (1) A few strands of tarred hemp may be well rammed in and the socket then filled up with rust cement, a mixture of iron shavings and chemicals which ensure rapid consolidation by the oxidation or rusting of such shavings; (2) a few strands of spun yarn dipped in a mixture of red and white lead, followed by a few strands of tarred hemp, and then rust cement; or (3) as last, but no rust cement, using instead a mixture of red and white lead with chopped hemp, a small quantity of gold size being added to hasten the setting of the joint.

Flanged Joints. If flanged joints are used, the abutting flanges are bolted together, with packing between. For low-pressure hot-water work, the packing between the flanges may be either asbestos or india-rubber; for low-pressure steam, asbestos; and for high-pressure steam, corrugated brass rings smeared with red and white lead.

Expansion Joints. If expansion bends are not used, expansion joints must be. There are very many forms, but two examples will suffice to show the general idea. Fig. 97 shows the "Jones" joint, which is formed as follows. The pipes have no sockets, and are butted end to end at a little distance apart to allow for expansion. Around the abutting ends is a flat iron ring, and on either side of this a rubber ring, shown by fine dots in the section. These three rings are secured by two collars, bolted together as shown. The great advantage of this joint is that plain tubular pipes can be utilised, and its disadvantage that it is only suited to low pressures and temperatures, owing to the use of rubber rings.

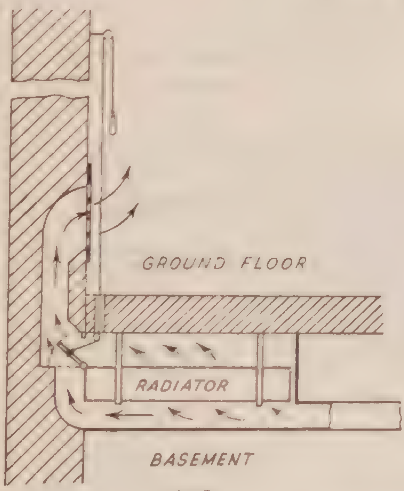
A better form of joint is that shown in Fig. 98, in which no rubber rings are used; the joint consists of an inner and outer tube sliding one within the other. At A is a packing of hemp treated in various ways, the screwing up of a cap, B, making the joint thoroughly watertight by the compression of the packing.

Pipe Movement. The pipes must be free to move with the expansion and contraction and, if long, may be supported on rollers, either one over the other or side by side. With shorter



CAST-IRON "PANEL" RADIATOR
(OTHER MODELS RIBBED BOTH SIDES AND HELD 2 INCHES AWAY FROM WALL BY LUGS)

99



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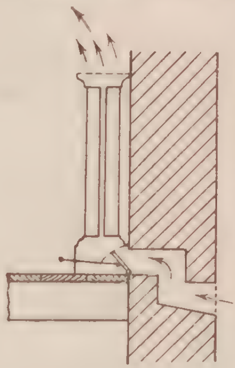

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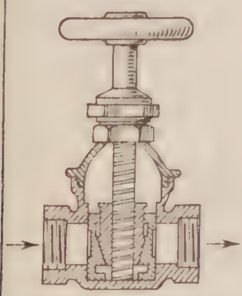

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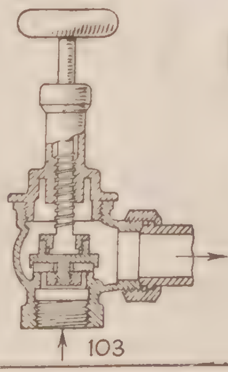

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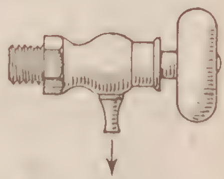

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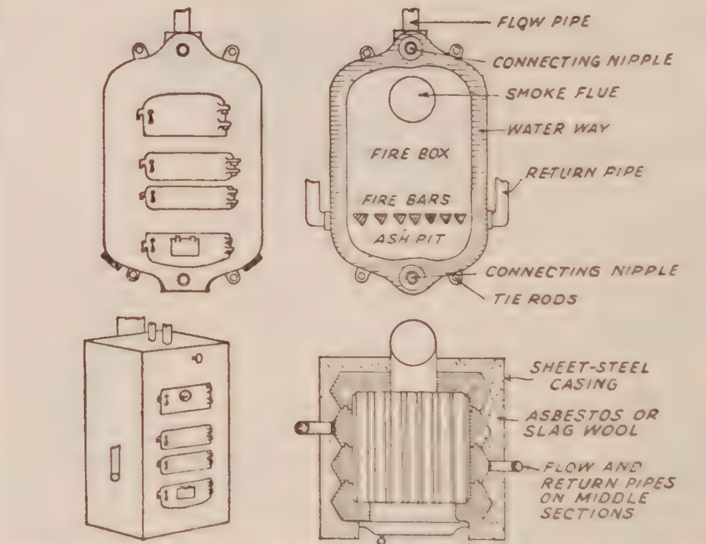
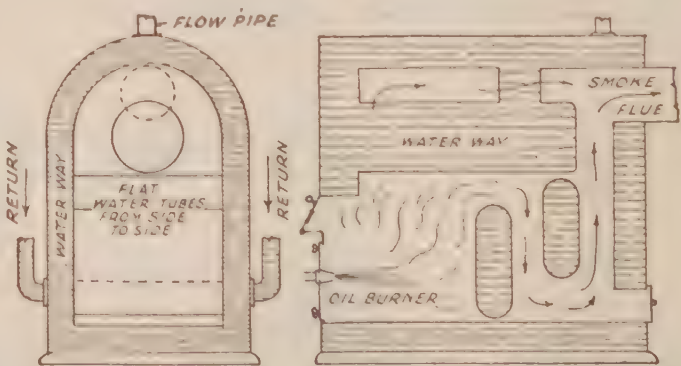


SMALL SECTIONAL BOILER (ELEVATION, MIDDLE SECTION, PERSPECTIVE, SHOWING SHEET-IRON CASING AND PLAN)

105



MEDIUM SIZE OIL-FIRED BOILER. CROSS AND LONGITUDINAL SECTIONS

106

pipes the rollers are unnecessary, but the pipes should be supported in clips or links so that a small longitudinal movement is possible, or, if embedded in chases in the walls during erection, they should be in hair felt or asbestos composition, so as to insulate them without preventing their movement when the temperature changes. The clips or links are in two or more pieces, bolted or screwed together after the pipe is placed in them, forming a circular support rather larger in internal diameter than the outside diameter of the pipe.

Radiators. The next point to consider is the provision for radiation. This can take various forms. Thus, the simplest is to use fairly large pipes, of say 3 to 4 inches in diameter, placed round the walls. This method, though suitable for a greenhouse or garage, is unsuitable for a dwelling-house. Not only would the pipes be an eyesore, but they would readily collect dust. In small public halls the method is sometimes used. One thing that cannot be too strongly condemned is the placing of hot water or steam pipes in a trough formed in the floor and covered by a grating. Dust gets swept through the grating, and is often roasted by the heat, causing serious nuisance. It is a little better to put the pipes in a chase formed in the face of the wall, with a vertical grating in front of them, but here also there is the difficulty of the accumulation of dust in an inaccessible position, which should always be avoided.

The best method is that of using upright radiators, built up in sections. Radiators may be classified as direct, indirect, and direct-indirect.

Direct Type Radiators. The direct is the ordinary type, placed about 3 inches from the wall. They should be placed against outside walls, preferably under windows, to check the cooling action of the window on the air of the room. They usually extend down to within a few inches of the floor, and the space below and behind is apt to become a receptacle for dust in the absence of good supervision.

Manufacturers generally keep many different sizes and types in stock, the most popular being perhaps 2 feet 6 inches to 3 feet in height. Each section may be of one, two, three or even more tubes, connected together at top and bottom, while each section is provided with a "nipple" (or shallow socket and spigot) at top and bottom, for making a watertight joint when bolted together. Probably the single column type is the most efficient, as the heating surface is spread out over a wider area and the projection into the room is less, but, of course, a larger area of wall is monopolised,

which may make the arrangement of the furniture more difficult. A selection of types is shown on page 129.

The size of the tubes varies a good deal in different makes, but an average single column radiator 3 feet high will give a radiating surface of about $3\frac{1}{2}$ square feet per section. The number of sections used can be modified to suit the heating requirements, the sections being bolted together by rods or bolts passing through the connecting nipples.

Usually the two end sections are supplied with dwarf legs to form the floor supports, though types which rest in lugs or brackets built into the wall make it easier to keep the floor clean underneath.

Another, and even better type, is hinged to the wall by "universal" joints on the flow and return pipes. This form, on unfastening a clip or thumb screw at the opposite end, can be swung out and away from the wall, like a gate, making thorough cleaning possible. This form is usually described as the "Hospital" type, owing to the fact that its benefits are seldom appreciated except in hospital work. "Panel" radiators (shown in Fig. 111) consist of units moulded in one piece, with the hot-water tubes moulded on the back of a flat cast-iron plate or panel. A simple moulding frames the outer edge, to provide finish, and the inlet and outlet connections are at the back. Owing to the conductive capacity of the iron, the heat is conducted from the tubes into the metal web in between them, giving a larger area of rather milder warmth, while the smooth face gives very little lodgment for dust or dirt. They are designed for fixing to the wall by lugs or brackets built in, and they can be fitted close to the wall with an insulated slab behind, to prevent loss of heat into the wall, or a space of 2 or 3 inches may be left behind the radiator, so that the air may pass freely over both back and front for warming. The surfaces are better left as plain as possible for the sake of easy cleaning. A dull black surface is probably the best for radiators, although research has shown that there is very little loss of efficiency when colours other than black are used. A bronze or mineral paint should be used, as oil paint may blister and cause unpleasant smells if the radiators become really hot.

Indirect Type Radiators. Indirect radiators are purely ventilating radiators, being intended to warm the fresh air as it enters. Fig. 61 illustrates one such form, placed in an air chamber under the floor. It may, of course, be disposed in any convenient cavity, either in the floor or behind panelling at the base of the walls. Gilled pipes, such as were shown in Fig. 77, are generally used to give greater heating surface. The air chamber is connected to

the open air by a duct leading to a grating in an external wall, while a damper or valve, in the passage leading to the inlet grating, provides for proportioning of the cold and warm air admitted into the room.

Direct–Indirect Radiators. The "direct–indirect" is the best form of ventilating radiator to install, since it provides complete control and enables the attendant to warm the air already in the room before the occupants arrive, or to maintain the purity of the air and its warmth when the room is fully occupied.

One form is shown in Fig. 60, under the heading of ventilation, and consists of a radiator with baffle plates at front and back. A better example, however, is that shown in Fig. 62. The radiator has no baffle plates and consists of hollow vertical sections through which the hot water circulates. It is covered by a grating at the top, has an air inlet at floor level, with a combined damper and "hit and miss" ventilator at its base. Thus, if the "hit and miss" valve is open the damper is shut and only the air of the room is warmed by the radiator. If the "hit and miss" is closed the damper is automatically opened and the incoming air is warmed.

Radiator Control Valves. Stop valves must be provided at the inlet of each radiator in order to permit of the regulation of the temperature. Where there are several branch services, valves are also necessary on them, in order to regulate the uniformity of the circulation of the water. There are many varieties of stop valve, and it will be sufficient just to give an idea of their construction and desirable points. Whether they are placed on a straight length of pipe, or at a bend (or elbow), they should be of such a form that when fully opened they permit of a full-way flow through them. Fig. 102 shows a section of one suitable for a straight length of pipe, and termed a "gate" valve. The handle should be of wood or other non-heat-conducting material, and is connected to a vertical shaft having a screw thread on it. A few turns of the handle raises the gate and leaves a clear way through the pipe. It can, of course, be only partially opened if desired. Fig. 103 shows a section through a valve at an elbow. Here also a few turns of the handle raises the washer from its seating in order to leave a clear way through. The inlet pipe to the radiator is shown on the right and the socket to receive the supply pipes is at the bottom.

Key Valves. In addition to the hand valves provided at the inlet, for regulation by the occupants, key valves are sometimes provided on the outlet (or return pipe) from each radiator, often under the floor or behind the wall panelling, so that the installing

engineer can adjust the maximum warmth to be provided in each room. The occupants can then adjust the warmth up to this maximum only.

The use of key valves of this type enable finer adjustments to be made to the system than can be done by altering the size of supply pipes, and greatly reduces the number of stock sizes of pipes which need be used in a given installation.

Air Cocks. As most natural waters contain in solution a good deal of air, which is driven off on heating, air valves must be provided at the side of the radiators, just near the top, to allow of the escape of air. They need to be opened only very occasionally, to release any accumulation of air. They can be either operated by hand in this way or be automatic in action. The more usual form in domestic work is that operated by hand or with a key and illustrated in Fig. 104. The automatic forms are often used on large installations, but they are somewhat liable to get out of order and should only be used where there is an engineer handy to attend to them if required.

Emptying Out Cocks. There is another position in which a valve is required; that is, on the return pipe near the boiler, so that the pipes can be emptied if desired. For this purpose an ordinary draw-off cock or valve is used, but with a hose union instead of a "bib".

Radiator Calculations. It has already been pointed out that the installation of a large heating system is a matter for an expert, but some idea may be given of the method of finding the size of radiators and the quantity of radiating surface required for simple cases. This depends partly on the quantity of air to be warmed, partly on the number of square feet of heat absorbing surfaces in the room, such as floor, walls, ceiling and windows, and partly on the relative temperatures of the pipes or radiators, the external air and the desired temperature of the internal air.

A good deal of valuable experimental work has been carried out by Dr. Margaret Fishenden and others, and delicate testing apparatus has been evolved for finding the insulating properties of different forms of building material, and a brief introduction will be given to the method of utilising their findings, but students wishing to specialise will be referred to the treatises of the Fuel Research Board and to volumes devoted to heating and ventilation entirely.

Approximate Formulae. For general use in small schemes a formula will be given which embodies the most important of these findings without going into the finer detail:

$$S = 1{\cdot}25 \frac{(T - t)}{(P - T)} \times \left(G + \frac{W + F + C}{10}\right),$$

in which

S = number of square feet of radiator surface required.
T = temperature in degrees F. required in the room.
t = average winter temperature (say 30° F. for southern England).
P = temperature of pipes or radiators, say 160°–180° for low, to 250°–300° for high-pressure hot water, and 180°–220°, and 250°–400° for low and high-pressure steam respectively.
G = number of square feet of glass in windows.
W = ,, ,, ,, wall surface.
F = ,, ,, ,, floor space.
C = ,, ,, ,, ceiling.

Heating engineers in this country look upon 60° F. as a satisfactory temperature for living rooms, as against 65° F. on the Continent and 70° F. in the United States.

It will be seen that the heating agent is the difference in temperature of the radiators and the air of the room ($P - T$), while the work to be done is represented by ($T - t$), which is the rise in temperature from the outside air to that desired inside.

The 1·25 is intended to allow a 25 per cent. margin of heat-loss owing to a normally efficient ventilating scheme. It can be decreased if the ventilating scheme is more than usually efficient.

If there were no loss of heat from the room other than that provided by ordinary ventilation, there would be no need for the last part of the formula, but much heat is lost through the thin glass of an ordinary window, while each square foot of plastered brick wall, floor and ceiling has been shown, on the average, to absorb $\frac{1}{10}$ of the heat going to waste through 1 square foot of ordinary window glass.

W can be divided by a smaller figure if the walls are of a more conductive material than ordinary solid brickwork as, for example, heavy concrete, while C can be modified for a hall in which there is an open roof.

The formula can be used to give the number of feet run of pipes needed (when hot-water pipes are used instead of radiators), by taking out the total number of square feet of radiating surface, and dividing this by the number of square feet in the surface of 1 foot run of the piping. For 4-inch piping, the formula may be taken as giving the number of feet run required without any

special adaptation, because the circumference will be roughly 12 inches.

When the figure has been found, it will have to be increased if the building is very exposed, or if it is only heated intermittently, as in the case of a church or assembly hall.

Size of Radiators. Suitable radiators can then be found by finding the number of square feet of radiator surface per section of the radiator type selected and dividing it into the number of square feet of radiator surface required, when the number of sections to be ordered will be found.

Heat Transmission Factors. Students of general sanitation will probably be satisfied with an approximate formula for heat requirements, but heating engineers need to be rather more careful, and to allow for heat losses according to scales of heat-transmission factors for different building materials and for varying conditions, as built up experimentally by the Fuel Research Board and other scientists. These will naturally vary a little one from another, but a very generally accepted scale is one published by the Institution of Heating and Ventilating Engineers under the title "Heat Requirements for Buildings" and obtainable from any bookseller. The following list and worked example (p. 123) is given in skeleton form and are intended to indicate the method. It is given by way of example only and is not intended in any way to be a complete exposition of the matter, for which the reader is referred to text-books specialising in heating and ventilation.

The heat-transmission coefficients are worked out in the laboratory as a number of B.Th.U. passing through a square foot of a given substance in a standard thickness of 1 inch in 1 hour for 1 degree (F.) difference in temperature of the air on either side of the material. This is the most convenient form in which to compare the insulating value of different building materials.

Utility Heat Transmission Factors. For practical use by the heating engineer, however, these are converted into Utility Heat Transmission Factors for forms of construction and typical thicknesses and combinations of material, such as 9- or 13½-inch solid brick walls with internal plastering or 11-inch cavity brick walls and the like.

Conversion from Laboratory to Utility Values. Students interested may like to see how the laboratory coefficients are converted into utility factors. The formula generally used is:

$$\frac{1}{U} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{X_1}{C_1} + \frac{X_2}{C_2} + \frac{X_3}{C_3} \ldots \text{etc.}$$

where

U = Utility Heat Transmission Factor used in Table I.
K = an experimental constant to show "surface tension" or heat resistance, inside and out,
X = the thickness of materials used in the layers 1, 2, 3, etc.
C = laboratory Heat Transmission Factor of the materials used in layers 1, 2, 3, etc., but in 1 inch of thickness

Example Working. For the sake of illustrating its use take a composite wall consisting of 4-inch stone facings, backed by 9 inches of stock brickwork and ½ inch of plaster inside.

Assume also that the following are extracted from a list of Laboratory Heat Transmission Factors for the kind of stove, brick and plaster used in B.Th.U. per hour for 1 inch thickness of material for each degree (F.) difference in temperature from one compartment to the other through the material in the testing apparatus:

Ref.	Material	Heat Transmission Factor for 1 inch
1	Brick	8·00
2	Stone	12·00
3	Plaster	4·00
4	Inside surface tension .	1·43
5	Outside surface tension .	6·00

$$\frac{1}{U} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{X_1}{C_1} + \frac{X_2}{C_2} + \frac{X_3}{C_3} \ldots \text{etc.}$$

$$= \frac{1}{1\cdot 43} + \frac{1}{6\cdot 00} + \frac{4}{12\cdot 00} + \frac{9}{8\cdot 00} + \frac{0\cdot 5}{4\cdot 00},$$

$$= 0\cdot 7 + 0\cdot 1\dot{6}\dot{6} + 0\cdot \dot{3}\dot{3} + 1\cdot 125 + 0\cdot 125,$$

$$\frac{1}{U} = 2\cdot 45,$$

and $$U = \frac{1}{2\cdot 45} = 0\cdot 408 \text{ approx.}$$

It is not usually necessary for the heating engineer to work out these Utility Heat Transmission Factors for himself, for the

Institution of Heating and Ventilating Engineers (in collaboration with other bodies) publishes a very full list of the values worked out for almost every thickness and combination of material likely to be met with in ordinary buildings and varied for a large number of different degrees of exposure to the wind and weather outside the building.

A brief extract from the "average conditions" column of such a list is shown here in Table I in which the column marked "Typical Heat Transmission Factor" gives the number of B.Th.U. passed per square foot per hour for each degree (F.) difference in the internal and external air for average conditions.

Example of Use. It is required to work out the number of square feet of radiator surface needed to make good the heat losses in a room 20 ft. × 12 ft. × 10 ft. high with 13½-inch brick walls plastered inside; windows $\frac{1}{10}$ floor area; tiled roof above with boarding, sarking felt, roof space and plastered ceiling. One door 6 ft. 6 in. × 2 ft. 6 in.; wood floor on joists, air space, 6-inch concrete under.

TABLE I

Table of Specimen "Utility" Values

Material	Typical Heat Transmission Factor in B.Th.U. per hour per degree (F.) diff.
Windows (21-oz. glass)	1·00
4½-in. brickwork and plaster	0·50
9-in. " "	0·40
13½-in. " "	0·33
11-in. cavity wall and plaster	0·29
Wood floor and plaster ceiling (cold air overhead)	0·17
Wood floor and plaster ceiling (cold air underneath)	0·07
Joist floor, air space and 6-in. concrete (ground floor)	0·25 (but very variable and much higher if well ventilated)
Tiled or slated roof, sarking felt, boarding, roof space and ceiling (typical good construction)	0·30 (much higher with poorer construction)
Wood doors	0·50 (varying with thickness)
Iron of radiators	1·5 (varying with type and conditions)
For ventilation—1 cu. foot of air raised 1° F. will absorb	0·019 B.Th.U.

TABLE II

Tabulated Set of Workings

Ref.	Material	Dimensions in sq. feet	Heat Transmission Factor	Difference in Temperature	Heat Losses in B.Th.U. per hr.
1	Walls	600 ×	0·33 ×	(60 − 30)	= 6000
2	Windows	24 ×	1·00 ×	(60 − 30)	= 720
3	Door	16 ×	0·50 ×	(60 − 30)	= 240
4	Roof, etc.	240 ×	0·30 ×	(60 − 30)	= 2160
5	Floor, etc.	240 ×	0·25 ×	(60 − 30)	= 1800
				Heat losses through fabric	= 10,920
6	Heat losses through change of air (say 2 per hour)	2400 ×	0·019 ×	(60 − 30)	= 2736
				Total heat losses in B.Th.U. per hour	= 13,656
	Heat to be added to room from radiators must balance the losses, thus;				
7	Radiators	x ×	1·5 ×	(160 − 60)	= 13,656

Hence no. of sq. ft. of rad. surf. $= \dfrac{13{,}656}{1 \cdot 5 \times 100} = $ 91 sq. ft.

It is to be heated by low-pressure hot-water radiators up to 60° F., with outside air taken as 30° F. and 160° F. as the average temperature of radiators. (See Table II.)

Selection of Suitable Boiler. Once the size and number of the radiators has been decided upon, it is not a difficult matter to select, from makers' catalogues, the size and type of boiler best suited to feed them.

Makers' catalogues usually tabulate the types and sizes of boiler, so as to compare not only their external and internal dimensions, but also the number of British Thermal Units of heat they are capable of emitting (given average working conditions and reasonable handling) and the number of square feet of radiator surface they are capable of maintaining at a reasonable standard of warmth.

"Hot Water" and "Heating" Rating of Boilers. One rather curious anomaly, which may be noticed by the student, is the fact that such catalogue data will often give the capacity of small domestic boilers with one value in B.Th.U. for hot-water heating

and with quite another value in B.Th.U. for radiator heating, the apparent heating efficiencies being in the ratio of about $2\frac{1}{2}:1$.

This may be explained by the fact that the boiler for the hot-water service receives cold water at perhaps 45° or 50° F., which, coming in contact with the hot boiler plates, absorbs the heat (by conduction) rapidly, when it rises up the flow pipe to be drawn off for domestic use and replaced by more cold water, and comparatively little of the heating value of the fuel goes to waste up the flue.

In the radiator service, on the other hand, the water from the return pipe enters the boiler at a much higher temperature—perhaps 150° F. or even more—so that there is a much smaller difference in temperature between the water to be heated and the boiler plates, the water, in consequence, being less receptive of heat and far more of the heating value of the fuel goes to waste up the flue.

Use of Common Boiler for Hot Water and Radiators. In small domestic installations, the householder is often tempted to save boiler space and labour in stoking by using a common boiler for the double duty. There are, however, serious disadvantages in combining them, including:

(*a*) The fact that the radiators are usually cast iron and will rust and discolour the water drawn off for domestic use.

(*b*) If the water supply is hard, and no softener is used, a deposit of scale will accumulate in the radiators and heating circulation, impairing their efficiency. (This deposit is negligible in the ordinary heating installation, as practically no fresh water is introduced and the first deposit of lime is, to all intents and purposes, the last.)

(*c*) The control of the radiator system is impaired, since one or two baths taken in succession will draw the hot water not only from the cylinder or tank, but also from the radiators, which will go stone cold until the water can be warmed once again in the boiler.

(*d*) There is less real economy, since a much larger boiler will need to be installed for the joint duty than would be needed for hot water alone, and this will need to be run all through the summer months for hot water only, when quite a small boiler would have served.

It is usually found far more satisfactory, if the space can be spared, to install a small boiler for hot water, to be kept going all through the year, and a larger one for the radiators, which will be in use only during the colder months.

Calorifiers. If, however, the householder decides upon a combined boiler, some of the disadvantages can be avoided by the use of a "calorifier". This, in its essentials, consists of a radiating unit inside a cylinder or indirect boiler. It may take the form of an annular or double cylinder inside the principal one, as illustrated in Fig. 107. The very hot water from the boiler then circulates in the primary circuit, through the radiators, including the interior cylinder, but it cannot communicate with the draw off taps of the domestic hot-water supply. The primary circuit may then be either low-pressure, with its own expansion pipe; or high-pressure, with an expansion chamber or compensation tank with Stainton Valve (as in Fig. 129 later), but the high-pressure type should not be recommended if the system will be in charge of an average housewife or housekeeper.

The secondary or draw-off circuit must always be low-pressure, for any attempt to superheat the water in the draw-off system would inevitably lead to scalding.

Conversion of Boiler Rating. If the double-purpose boiler is employed, or if a boiler intended primarily for radiators is used for hot-water supply, or vice versa, it may be necessary to convert the heating requirements from one rating to the other, thus:

It is required to select a small domestic boiler from a catalogue which gives heating capacity in B.Th.U. for domestic hot water supply only. The householder desires to install a boiler which will provide 60 gallons of hot water per hour for domestic use (raised say from 50° to 150° F.) and will also keep three radiators (each of 50 square feet) at a temperature of 160° F. when the temperature of the air in the room is 60° F.

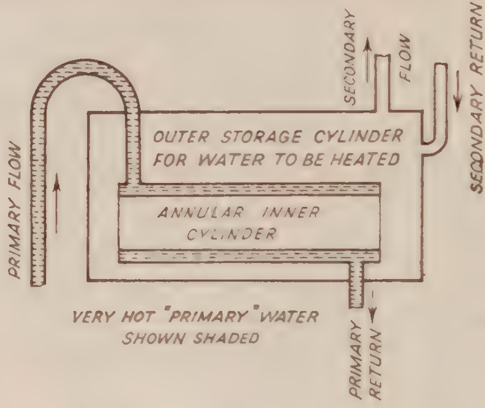
It will be necessary first to find the total number of B.Th.U. per hour required to do this work in "Hot Water Rating".

Each gallon of water weighs 10 lb., so 60 gallons weigh 600 lb.

1 B.Th.U. is the quantity of heat required to raise 1 lb. of water 1° F., so 600 lb. of water will require 600 B.Th.U. to raise it 1° F., or 60,000 B.Th.U. each hour to raise 60 gallons an hour 100° F. (i.e. from 50° to 150° F.).

Radiators are found, experimentally, to be capable of transmitting $1\frac{1}{4}$ to $2\frac{1}{2}$ B.Th.U. of heat from the water to the air per hour for each square foot of surface for each degree F. difference in temperature, the rate of transmission depending mainly on the relative temperatures of the radiator and the air to be warmed. $1\frac{1}{2}$ B.Th.U. per hour is a fair rate to assume for average conditions.

150 square feet of radiator surface will therefore emit 225



ANNULAR STORAGE TYPE CALORIFIER
107

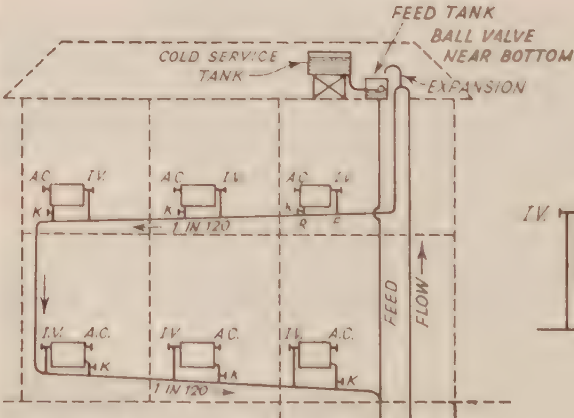
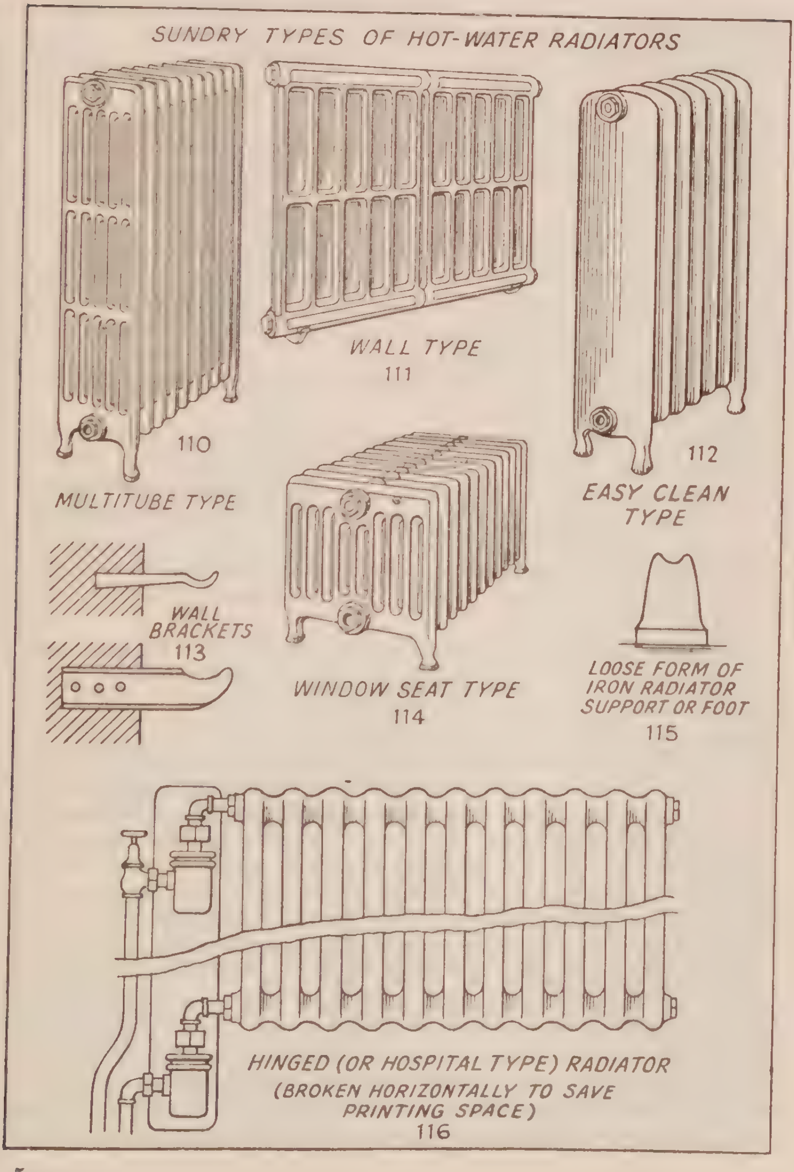


DIAGRAM OF
HORIZONTAL
"ONE-PIPE" SYSTEM

(MOST SUITABLE FOR FAIRLY SMALL ONE
OR TWO STOREY BUILDINGS)
108

109


SUNDRY TYPES OF HOT-WATER RADIATORS
WALL TYPE
111
110
MULTITUBE TYPE
112
EASY CLEAN TYPE
WALL BRACKETS
113
WINDOW SEAT TYPE
114
LOOSE FORM OF IRON RADIATOR SUPPORT OR FOOT
115
HINGED (OR HOSPITAL TYPE) RADIATOR
(BROKEN HORIZONTALLY TO SAVE PRINTING SPACE)
116

B.Th.U. for 1° F. difference and 22,500 B.Th.U. for 100° F. difference (i.e. from 160° to 60° F.).

To allow for the lower efficiency when used for radiator heating, as compared with hot-water supply, it should be still further increased in the ratio of 1:2½, hence:

Radiator requirements	in hot-water rating				= 56,250	B.Th.U. per hour		
Hot-water requirements	,,	,,	,,	,,	= 60,000	,,	,,	,,
Total requirements	,,	,,	,,	,,	116,250	,,	,,	,,

Some latitude should be allowed for variations in the quality of fuel used, in the skill of control and the like, and 20 or 25 per cent. would be a reasonable addition, bringing the total to (say) 145,000 B.Th.U. per hour, and the boiler with its hot water rating nearest to this figure should be chosen.

The same size of boiler will be rated for radiator heating at about 58,000 B.Th.U. per hour.

Principal Pipe Circuits. There are many methods of arranging the circulation pipes in low-pressure hot-water heating, but the principal forms are the "horizontal one-pipe" system, the "drop" (or "vertical one-pipe") system, the "two-pipe" system and "two-pipe system with risers".

Horizontal One-pipe System. The horizontal one-pipe system (shown diagrammatically in Fig. 108) is most suitable for low compact buildings.

In the one-pipe system the flow pipe rises to the highest point to be served by radiators by the most direct route, where an expansion pipe or tank permits trapped air or steam to get away. The pipe then falls, with a minimum gradient of 1 inch in 10 feet (or 1 in 120) all the way back to the bottom of the boiler, taking a somewhat tortuous route so as to feed the various radiators needed.

In this system, where the main supply pipe is approximately horizontal, the inlet and outlet of each radiator join the same pipe, as shown in Fig. 109. In order to obtain as much help as possible to the flow of convection currents, the inlet should come first in the direction of flow and the outlet second, the inlet being taken from the top of the pipe and the outlet being returned into the side.

The Vertical One-pipe or Drop System. The "drop" system (shown in Fig. 117a) is more suited to tall compact buildings designed on symmetrical lines, in which the radiators can conveniently be arranged one above the other on the various floors. As with the horizontal one-pipe system, the flow pipe rises straight to the top of the building, where the expansion pipe or tank is placed.

Fig. 117b shows how the radiator connections are made, the outlet

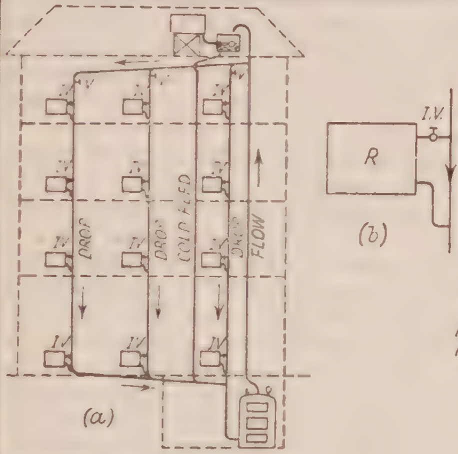


DIAGRAM OF "DROP" SYSTEM
(MOST SUITABLE FOR FAIRLY SMALL BUILDINGS ON SYMMETRICAL VERTICAL LINES)
117

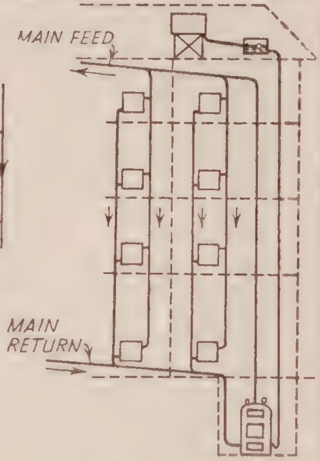


DIAGRAM OF PART OF TWO-PIPE DROP SYSTEM
118

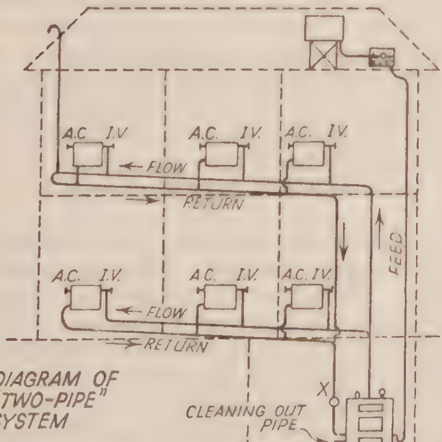
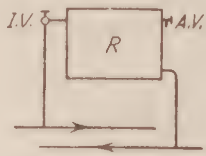
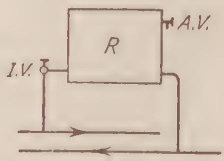


DIAGRAM OF "TWO-PIPE" SYSTEM
(SUITABLE FOR ALL TYPES OF BUILDING, BUT MAY NEED ACCELERATION WITH A PUMP AT X IN "WIDELY SPREAD" BUILDINGS)
119



120



121

being taken down a little way before joining the main pipe, as this method gives better results than taking it straight across as shown for the inlet. The inlet valve is lettered I.V. It will be noticed that there is no air valve in Fig. 117, the reason being that it is unnecessary with that method of connection, since the air can escape through the inlet pipe.

There are varieties of both the one-pipe systems. Thus, in a building of one storey only, the main circuit of piping is taken vertically up from the boiler to as high a point in the basement as possible and then passes round the building, falling all the way back to the boiler, to which it is connected low down at the side. Short branches, if they must be approximately horizontal, should have a fall of not less than 1 inch in 5 feet.

With a building of two storeys it is possible to arrange the pipes in a similar way, taking the shortest route to the highest point for the flow pipe, circuiting round the upper floor, then vertically down to the lower floor and circuiting round that and on to the boiler as before. The disadvantage of all one-pipe systems is that it is difficult to ensure equality in temperature, the radiators farthest from the flow pipe being of lower temperature than those near it, since, of course, each radiator in series has to be fed with the "leavings" of its predecessors on the circuit.

Two-pipe Drop System. To alleviate the disadvantage of the system just described, each of the drop pipes is stopped at the lowest radiator in the tier, while a "return" is started at the outlet of the top radiator, connecting up with each of the radiator outlets on the way down and finally connecting to the main return back to the boiler. The method is shown in one tier of radiators in Fig. 118. Otherwise Fig. 117 remains unaltered. In this way, every radiator gets its own supply from the boiler and all cooled water goes straight back to be reheated instead of hot and cold mixing in the radiators.

Dips in Pipe Line. It is sometimes necessary to dip the pipes to pass under doorways and similar features, rising again on the far side of the obstruction. Such dips form traps and obstruct the circulation; they should therefore be avoided wherever possible, but, if unavoidable, an air cock should be inserted at the top of the loop produced, so that any steam or air collecting there may be released. Dips of this type do least harm on the return pipe near the boiler, but they always slow down the circulation and, as the convection currents have far less power than the force of gravity, everything possible should be done to avoid friction or hindrance to flow.

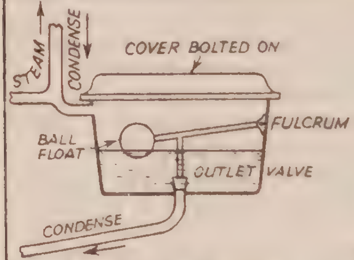
Cold Supply to Boiler. The cold supply should be taken either direct into the boiler or connected to the return pipe just before the boiler is reached, the supply pipe having a dip or trap at the point of connection, to prevent the hot water circulating up it to the feed cistern. An expansion pipe should be carried up as nearly over the boiler as possible, in the form of a continuation of the vertical flow pipe, and should have its upper end bent over the feed cistern. This allows for the expansion of the water in heating, and also for any discharge that may occur from it to occur in a place of safety.

Two-pipe System. Fig. 119 illustrates the ordinary two-pipe system. It is far more adaptable to irregularly designed buildings than the one-pipe systems, and it is easier to control the temperature, as each radiator has its inlet from the main flow pipe, while the branch return goes back, via the main return pipe, to the boiler, and there can be no question of one radiator being fed with the leavings of its predecessors.

In the two-pipe system the pipes are arranged to flow and return as before, but in a different way, the flow and return following the same course. Figs. 120 and 121 show this, and should be compared with Fig. 119. An inspection of Figs. 120 and 121 will show that they give different positions for the inlet in the two cases. The top inlet shown in Fig. 120 is the more efficient, but the bottom inlet shown in Fig. 121 is the neater in appearance, being only a little above the floor. The difference, however, is apparent rather than real, for when the inlet is taken in low down, the bottom connecting nipple between the first and second radiator sections is blocked up, and the first section then acts as an inlet pipe as well as being part of the radiator. When this is done the inlet control valve is often of a different pattern, being placed with its working parts in the connecting nipple between sections 1 and 2 at the top, and the handle is then placed horizontally beside the top of the first section and right opposite the air-cock.

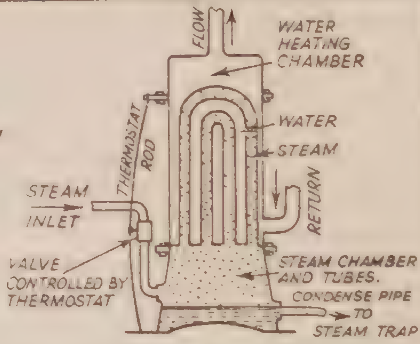
Two Pipe with Vertical Risers. The two-pipe system with vertical risers is shown in Fig. 126. Its chief advantage is seen in office or factory blocks in which the floor plans are more or less stereotyped, so that the radiators can be arranged in tiers one above the other. It is not so easy to hide the pipes unless the walls are panelled, enabling the pipes to be hidden behind the panelling.

Pipes in Ducts or Chases. If the pipes are run in chases left or cut in the walls, care must be taken to insulate the heat and to permit free expansion and contraction. Pipes embedded in this way are often wrapped first in canvas-backed asbestos fibre or in



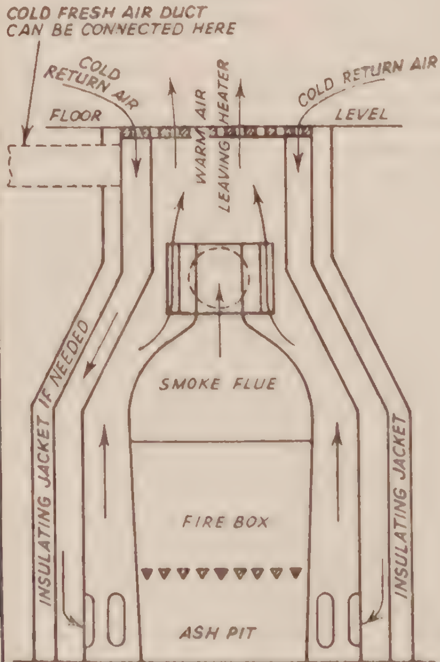
STEAM TRAP TO RELEASE "CONDENSE" IN BIG STEAM CIRCUITS

122



STEAM CALORIFIER

123



"ONE-PIPE" HEATER

124

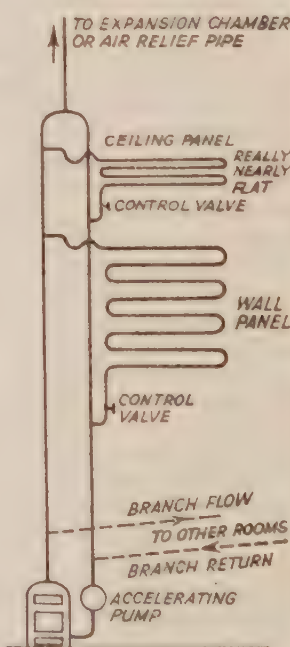


DIAGRAM OF PART OF PANEL SYSTEM

125

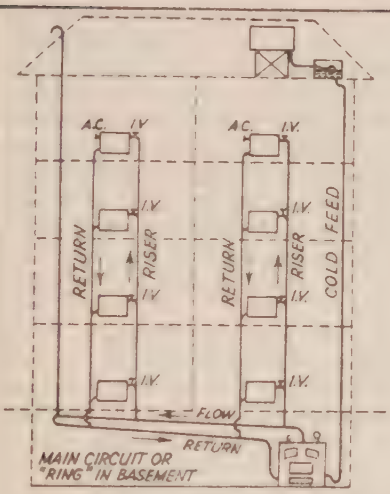
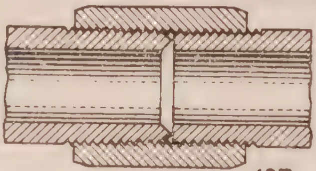


DIAGRAM OF "TWO-PIPE" SYSTEM WITH RISERS.
(AIR COCKS NEEDED ON TOP RADIATORS ONLY.)
SUITABLE FOR LOFTY BUILDINGS WITH SYMMETRICAL PLANNING

126



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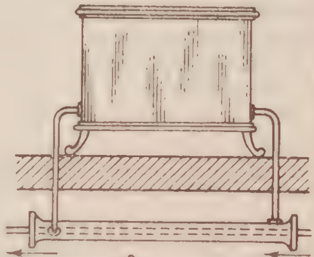

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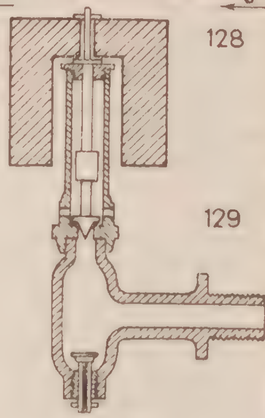

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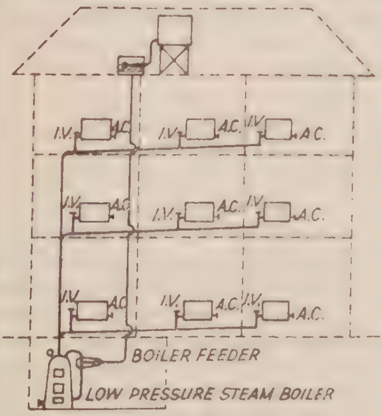

LOW-PRESSURE STEAM SYSTEM.
"ONE-PIPE" CIRCULATION WITH STEAM AND CONDENSATION WATER IN SAME PIPES

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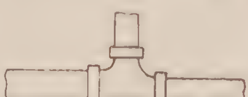
131



132

hair felt. A closely fitting metal collar is often placed round the pipes where they emerge from the plaster of ceilings and walls, or from the timber of floors, so that a neat but non-rigid joint is possible. Too tight a joint will damage the plaster and result in all sorts of weird noises in the dead of night, or in the early morning, as the pipes contract or expand with changes in temperature.

Each system of arranging the pipes has its advantages and disadvantages, and those of the one-pipe system are as follows: The advantages are economy, and the fact that there is no liability to short-circuiting; i.e. no radiator can escape being supplied. On the other hand, it is not so suitable as other systems for a building of several floors.

In the overhead or drop system the flow pipe is taken to the highest point straight away, and then split up into several vertical returns, which are collected together at the bottom into one main return. The system is particularly suitable for a high building, if the radiators are arranged one over the other on the various floors. The advantages beyond this are that the large amount of vertical piping ensures a rapid circulation and permits the use of smaller pipes, and no air valves are needed.

Choice of Circuit. The two-pipe systems should be considered the most satisfactory, especially for large or irregularly planned buildings—the two-pipe system with risers being chosen when all floors are much alike. The system is rather more expensive to install, but it gives much better control, as the cooled water from radiators is taken straight back to the boiler to be reheated and does not cool the water in the main circuit.

Accelerated Heating Schemes. These are conventional high- or low-pressure heating circulations of the ordinary one-pipe, drop, two-pipe and similar design in which the design of the building or the long horizontal travel makes it difficult or impossible to obtain a sufficient circulation by gravity. It then becomes necessary to instal an accelerating pump. This is usually on the return pipe just before returning to the boiler, where the water is coolest and the working parts least likely to be affected by excessive expansion and contraction. Such pump is generally worked by electric motor (as least troublesome), the pump being of centrifugal type as being most free from valves. The inclusion of such a pump, in speeding up the circulation tends to increase the efficiency of the boiler, as the transfer of heat from the boiler plates to the water is more rapid.

Pipe Sizing. The size of pipes needs to be worked out with extreme care if the heating capacity of the radiators is to be in

any way controlled by them. This control, as has been shown, is contrived mainly by the size of the radiator, the hand valve on the inlet and (sometimes) the key valve on the outlet, so that exact pipe sizes are not necessary, provided they are large enough to carry the volume of water needed. In an efficient low-pressure hot-water system, with a mean temperature of 180° F., branch pipes $\frac{3}{4}$ inch in diameter will be sufficient for inlets and outlets, and the mains leading to them can be made of a sectional area large enough to equal that of the sum of the inlet branches, worked out by the rule of similar figures. Thus, if D is the diameter in inches of main supply pipe and d the diameter of twelve $\frac{3}{4}$-inch inlets to radiators to be served thereby, the main supply should be worked out so:

$$\frac{D^2}{12} = \frac{d^2}{1},$$

$$D^2 = \left(\frac{3}{4}\right)^2 \times 12,$$

$$D = \sqrt{\frac{3 \times 3 \times 12}{4 \times 4}} = 2\tfrac{1}{2} \text{ in. (approximately).}$$

In the same manner, and ignoring any alteration in friction, we might assume that, if one main supply pipe has to provide two loop mains with hot water, each loop being of $2\frac{1}{2}$ inches diameter, the trunk main should be such that:

$$\frac{D^2}{2} = \frac{d^2}{1},$$

$$D^2 = 2 \times 2\tfrac{1}{2} \times 2\tfrac{1}{2},$$

$$D = \sqrt{\frac{2 \times 5 \times 5}{2 \times 2}} = 3\tfrac{1}{2} \text{ in. approximately.}$$

Lagging. Where pipes pass through rooms not requiring to be warmed, or where the warmth would be wasted, a non-conducting covering or lagging should be used, the materials suitable for boilers usually being suitable also for pipes.

High-pressure Systems. The high-pressure system of hot-water heating was introduced early in the nineteenth century by Perkins and is still often referred to as the Perkins' system. The method of installing the system has varied but little since it was first introduced. Whereas the low-pressure system is open to the atmosphere, through the medium of the expansion and air pipes, the high-pressure system is hermetically sealed. Broadly speaking,

it consists of an endless pipe nearly filled with water, a coil of the pipe being placed in a furnace to act as a boiler. There should be about 10 feet run of pipe in the boiler coil for every 50 feet around the building.

It is a well-known fact that water boils at different temperatures when subjected to different pressures. Thus, at sea level, it boils at about 212° F., but at the top of a high mountain, where the pressure of the atmosphere is less, it would boil at a lower temperature. Similarly, at the bottom of a very deep mine, it would not boil until it reached a much higher temperature than 212°, because the pressure is greater. This phenomenon is utilised in the determination of heights, the science of determining heights by the relative boiling-point of water being termed hypsometry.

By eliminating the expansion pipe (or other means of maintaining atmospheric pressure), and strengthening the pipes and fittings to correspond, it is possible to heat the water to a much higher temperature without the water boiling. In the ordinary forms of high-pressure apparatus the pipes reach a temperature of about 250° to 300° F., and in any good installation valves are used to prevent a higher temperature being reached, since as high as 600° F. is quite a possibility. The pressure referred to above is obtained entirely by natural means, the expansion of the relatively incompressible water compressing the air.

The component units are the coil or coils forming the boiler, the pipes and joints, the expansion chamber and the filling pipe. No stop valves are needed in this system, neither are air valves used, as the air is dislodged when the apparatus is first charged with water, while that which is given out from the water during the heating accumulates in the expansion chamber. In the original "Perkins" system, no branch services were used, separate loops and boiler coils being employed, when extra tiers of radiators or radiating coils were needed, but in modern high pressure a more conventional type of boiler is employed and branch sections with welded joints are used where needed.

Boiler in Perkins System. The boiler is usually formed of a coil or coils of the same pipe as is used for radiation of the heat into the rooms. This method of arranging the coils gives several distinct pairs of flows and returns, each loop having its own expansion chamber, and so ensures a high temperature throughout.

Pipe Joints in H.P. System. Radiators are usually formed of the tubes themselves, sometimes just as they are, but more often embedded in semi-insulating plaster or concrete of walls, floor or ceiling, when the system is known as the "Panel" system.

The pipes are of strong welded wrought iron, $\frac{7}{8}$ inch in internal diameter and about $\frac{1}{4}$ inch thick. They are tested to a high pressure and temperature before leaving the factory. These tubes may be threaded at both ends with right- and left-handed threads respectively, the joint being made by means of loose collars, as shown in Fig. 127. No jointing material is used, but one end of each pipe is shaped as shown, so as to give a tight "metal to metal" joint when the socket is fully screwed up. Another method, especially suitable for the panel system, when the tubes are inaccessible, once they are embedded, is to use welded joints.

Expansion Chamber. The expansion chamber usually takes the form of a pipe 3 or 4 inches in diameter, fixed vertically or nearly so, with a screw cap at the top. It may, however, take the form of a coil.

Charging Plug. The apparatus is charged, in the first instance, through a plug near the boiler, but a recharging plug is provided just below the expansion chamber, for adding water as from time to time required.

The flow pipe should go to its highest point by the most direct route, in order to ensure a good circulation. Dips or traps in the pipes are not so difficult to deal with in this system, as the circulation is much more rapid than in the low-pressure method. The pipes should be fixed at least 3 inches from any woodwork. They can be exposed in the room, or, if this is objected to on the ground of appearance, they can be put behind a grating where the skirting of the room would ordinarily be.

If radiators of the conventional type are desired in this system, they are most conveniently heated indirectly by small calorifiers in the manner shown in Fig. 128. Below each radiator a large pipe or cylinder is put, of say 3 to 4 inches diameter, to the ends of which the ordinary small pipe is connected. From the larger pipe a flow is taken to the radiator, a return being taken from the opposite end. The method of connecting the flow and return has already been described and should be again noted in Fig. 109, the flow going from the top of the pipe and the return being connected to its side.

The Stainton Valve. Instead of the expansion chamber a valve may be used, fixed in a water tank. This valve can be adjusted to limit the pressure and the temperature to any desired figure. Fig. 129 shows a section through one form of such a valve, known as the Stainton valve. At the top, shown by hatched lines, is a weight, connected to a vertical spindle which has a conical lower end. The cone rests on a seating and when the pressure gets beyond the predetermined figure it automatically rises and lets

the water out into the tank. On the pressure falling below its normal amount, another small valve, at the bottom of the illustration, automatically rises and lets more water in. The spindle of this valve is not of circular but of cruciform section, so that a very slight rise of the spindle will let water in.

Water systems are liable to be interfered with by frost, if the furnace is allowed to go out in frosty weather. Anti-freezing liquids are obtainable which can be added to the water to prevent freezing, but a much better method is to take care that the boiler is not allowed to go out at such times.

Advantages of H.P. System. In concluding the description of the high-pressure system, its advantages and disadvantages may be briefly set forth. Its first cost is not great, unless the pipes are embedded (panel system); the pipes may be quickly raised to the desired temperature; a high temperature may be obtained, which is particularly desirable for some purposes, such as the drying-rooms of laundries and other businesses; and only a small quantity of water is used. On the other hand, there is danger of explosion if the system is not well designed; the temperature may become too high if a valve is not used, with the result that the adjacent air will be scorched.

Panel Heating. This is a system in which flat "grid-iron" shaped coils of heating pipes, generally with welded joints, are buried in the plaster of a wall or ceiling or in the concrete of fire-proof floor, these being invisible to the occupants and leaving the whole of the floor or wall area free for furniture, work-benches or such other usage as may be desired. The boiler is usually operated at high pressure, so the radiating pipes can be of small diameter—as small as ½ inch—and the spacing between the tubes can be about 6 inches so that the concrete or plaster in which they are embedded lowers down the final radiating surface to a temperature of 90° to 100° F. This lowering of the surface temperature of the panel reduces the amount of heat given off to the air by conduction and circulated by convection (especially in the ceiling panels) but has very little effect on the radiation effect, so a ceiling panel will give off as high a percentage as 90 per cent. by radiation while with wall and floor panels the ratio will be about 50 per cent. and 60 per cent. respectively, the remainder being circulated by convection. There is a far greater time lag in the initial heating up of the building in which it is installed, so it is quite unsuited to buildings which will be used intermittently, as in that case a lot of residual heat will leak away, but where a building is to be used all over and needs heating day and night, it is found to be a fairly economical method

of heating. Obviously it is not a system to be installed as an afterthought in an existing building. Indeed, it needs careful forethought and co-operation between the heating engineer designing the heating system, the architect designing the building and the teams of workers carrying out the work, so that the steelwork, brickwork, masonry, pipework, concreting, plastering and finishing can be co-ordinated as the work proceeds. It may be necessary to place an insulating layer behind the grid-iron piping if placed in wall panels in an external wall, or one where heat is not required on both sides or in floor or ceiling panels where rooms below or above require no heat or are in different occupation. As ceiling panels gridiron heating tubes can be clipped or wired to the reinforcing rods of the structure and adjacent to the centring or forms to take the concrete, which will be placed from above, leaving the pipes almost surrounded but on the lower face. The plaster finish is then added on the underside, with muslin scrim worked into the final coat to prevent crazing in the plaster surface. Lime plaster is the most suitable for the purpose. Care should be taken not to overdo the installation of floor panels, as the warmth conducted into the feet of occupants sitting still for long periods can be very tiring. Probably it would be wise to install floor panels only in cases where the occupants will be mainly on the move and not standing or sitting still for long together. A useful combination would be large ceiling panels, at not too great a height from the floor, to provide mainly radiant heat, in combination with smaller wall panels, to provide a little more radiant heat and a good proportion of convected heat to warm the air and circulate it around the rooms.

Wall panel systems can generally be designed to work by gravity alone, but floor and ceiling panels usually involve so much nearly horizontal tubing that an accelerating pump on the return just before entering the boiler is nearly always found necessary. A portion of a panel system is illustrated by diagram in Fig. 125.

Steam Heating. We come next to steam heating, which was proposed as far back as the sixteenth century, for we find Sir Hugh Platt, before referred to, writes: "For the keeping of any flowers abroad, as also seeds sown within doors . . . in a temperate heat with small charge, you may perform the same by hanging a cover of tin or other metal over the vessel wherein you boil youre beefe or drive youre buck, which, having a pipe in the top, and being made in the fashion of a funnel, may be conveyed into whatever place you shall think meete."

It was not, however, until the early part of the nineteenth century that a workable system was installed on very much the same lines as at present adopted. Steam systems are either "low" or "high" pressure according to whether the steam is kept at (or near) atmospheric pressure or is kept above it, 5 lb. per square inch above atmospheric pressure being taken as the dividing line.

Low-pressure Steam. In low-pressure steam systems, the steam circulates through strong wrought-iron pipes, laid so that the condensation water can drain back to the boiler. The principle of warming by steam is the rapid condensation of steam into water on coming in contact with cooling surfaces, the latent heat being given out at the moment of condensation. The quantity of radiating surface depends on the system of ventilation, the area of cooling surfaces, the accuracy of fitting of doors, windows, etc., and the desired temperature.

L.P. Steam Circuit. Greater care and skill is needed in designing a system of steam heating than with one for hot water, owing to the difficulty of disposing of the condensation water without annoyance from vibration or "water hammer". In steam work the pipes must be given a greater fall than is usual for hot water and care must be taken to avoid obstruction to the return of the condensation water to the boiler. Fig. 130 gives a rough idea of the application of a low-pressure steam system to a small building on one-pipe lines. If the steam pipes have to dip under a door or similar feature, provision must be made for carrying the condensation water away and back to the boiler. For the same reason "T" junctions in steam pipes should be constructed as in Fig. 131 rather than as in Fig. 132, so that there shall be no obstruction to the flow of the condensation water back to the boiler.

Radiators for L.P. Steam. The radiators can be of similar type to those used in hot-water work, except that the air-cock should be about $\frac{1}{3}$ from the bottom instead of at the top, so that the air, which is heavier than steam, may be expelled when the radiators are put into use at the beginning of the heating season. On opening the cock, the air can be heard emerging. Soon after steam begins to appear, the cock should be turned off. There may still be a little air left, but it will do no harm.

L.P. Steam Boiler. The boiler can be similar to that for low-pressure hot water, except that the top is usually domed to collect the steam and direct it into the steam pipes, while the feed tank is usually placed near the boiler instead of above the highest radiator.

Condensation Water and Steam Traps. If the system is an extensive one, involving long runs of nearly horizontal pipes as well as vertical ones, it is wise to put condensation water outlets at the junctions, with steam traps incorporated as in Fig. 122, so that the steam is kept in its proper course, while the "condense" can run back to the boiler by the most convenient route.

The expansion and contraction of the pipes is much greater than in the case of hot-water systems, and the changes of temperature are more rapid. Ample provision must be made for this, the difficulty being overcome by using expansion joints on the straight lengths, and plenty of bends where junctions and connections occur.

It is better not to fix steam radiators at a level lower than the boiler, but, if this is done, a steam trap must be placed on the outlet from the bottom of the radiator, so that the condensation water may be run away to waste without loss of steam, as it cannot be passed back to the boiler by gravity.

Steam Circuits. The methods of arranging the pipes and connections to radiators in steam work are very similar to those described for low-pressure hot water, i.e. the one-pipe, two-pipe, or drop systems. In the one-pipe system a single connection is used at the bottom of each radiator instead of two, the branch conveying the steam *to* the radiator and the condensation water *from* it. In the two-pipe system the steam is conveyed by the flow pipe to the top of the radiator and the water carried back by the return, whereas with the one-pipe system the single pipe conveys both steam and condensation water.

In the two-pipe system, each radiator has therefore both a flow and a return connection, with a valve on each. In the case of the drop system, there is usually only one connection to each radiator, as the system works better if radiators are not connected to the flow pipe; but if any radiators are served by the main flow pipe they should have two connections.

No matter which system is used each radiator should have an air valve near the bottom.

Dry and Wet Returns. In the two-pipe system, the return is sometimes connected to the boiler above the level of the water in it and sometimes below, the former being termed a dry and the latter a wet return. The condensed water may be pumped back, but in the low pressure it generally returns by gravitation, giving what is termed a gravity return.

Exhaust Steam Heating. Exhaust steam heating is a form of low-pressure warming in which exhaust steam, or steam which has been partly used in the cylinders of engines, is employed.

Such exhaust steam has about 90 per cent. of its original energy on leaving the engine and can well be utilised for such a purpose. As it leaves the engine, however, it contains oily, greasy matter taken up from the lubrication of the cylinders, and this matter must be removed by special apparatus before admitting it to the heating system, or it will lower the efficiency of the radiators. The drop system is the usual method of arranging the piping, the water of condensation being collected into a tank and pumped back to the boiler, it being usually heated before reaching the boiler, either by an "economiser", as used in conjunction with the supply of water to large steam boilers, or by some other method. The system can be arranged so that both exhaust and live steam are available for heating, but this complicates the arrangement and greatly increases its cost. Special combined air and vacuum valves are fitted to the radiators. The cost of running an exhaust system is low, by reason of using steam which would otherwise be wasted, but the system is a rather expensive one to install, owing to the fittings and apparatus required.

High-pressure Steam. High-pressure steam heating utilises superheated or "dry" steam at a pressure greater than 5 lb. per square inch above atmospheric pressure, 10 lb. per square inch being a good working pressure.

Steam Boilers and Calorifiers. The arrangement of the units in this system is similar to that just described, but a different type of boiler is used, such as the Cornish, Lancashire, water-tube, or multi-tubular boilers. The system is, as a rule, only adopted where steam at high pressure is used in the same building for other purposes than heating, or when several detached buildings have to be heated from a common, centrally situated, boiler-house. In such a case, well-lagged steam pipes will convey the dry steam over a wide area without difficulty, but the direct heat would be too great to admit safely into ordinary radiators, so it is usual either to embed the pipes in semi-insulating plaster panels (the "Panel" system), or to use a calorifier in each building to heat up the water for a low-pressure hot-water circulation, which can then be arranged with radiators in the ordinary way. Fig. 123 illustrates one form of steam calorifier.

Reducing Valves. Sometimes the steam for a low-pressure steam system is taken from a boiler which is principally used for generating steam at high pressure for the driving of machinery. In such a case a special reducing valve is used on the system, in order to reduce the pressure from high to low.

Atmospheric Steam Heating. A system known as atmospheric

steam heating is largely used on the Continent, but is not extensively used in this country. The boiler pressure is usually from 5 to 8 oz. per square inch. The pipes are arranged similarly to those in the low-pressure steam system, but a pipe is carried up from the upper end of each return pipe and left open to the atmosphere at the top. The lower ends of the return pipes are collected together and taken into an enclosed tank and thence into the boiler. The system is said entirely to overcome the difficulty of water-hammer.

Vacuum Steam Heating. Vacuum steam heating is a system which provides for increasing the efficiency of the radiators by extracting the air from them and thus accelerating the circulation. The return pipes are always in a state of partial vacuum, being in direct communication with an exhaust pump, which extracts the air and returns the water of condensation. In a vacuum, water will boil at a lower temperature than otherwise. Automatic valves are provided on both inlets and outlets of the radiators and at certain points on the pipes. In a system of this kind the temperature is much more under control than is the case with other steam systems. In a variation of this system termed the "Nuvacuumette", no valves are provided on the outlets of the radiators, which has the effect of causing a partial vacuum in both radiators and return pipes. The chief advantages claimed for the vacuum systems of heating are the following: the difficulties with regard to dips are easily overcome, there is economy of fuel compared with other steam systems and with hot water, there is no danger from frost or leaks, and the cost of the installation is not high, though greater radiating surface is required.

Advantages of Steam Heating. There are certain advantages incidental to steam heating as compared with hot water, the principal of which is that the radiators are quickly raised to their full temperature and soon cool down again if desired. On the other hand, a steam installation is more costly than one for hot water, both as regards first cost and annual maintenance, and the heat is apt to be dry and fierce, tending to scorch the air.

There is also a system involving the use of both steam and hot water. It is a rather complicated system, but the mixture of the steam and hot water greatly increases the velocity of the circulation in the system, and the heat can be better transmitted for long distances.

Hot-air Heating. Hot-air heating is usually carried out in conjunction with air-conditioning, as described in Chapter III under the heading of "plenum ventilation".

Air Heaters. Unit air-heaters were described in the early pages of this chapter, the Musgrave and Manchester grates being examples. "Central" air-heating stoves are not usually successful unless mechanical blowers or fans are employed to drive the heated air along the ducts to the apartments to be warmed. Even so, they need careful design to avoid roasting or drying of the air and it is seldom that sufficient access is provided for cleaning away the dust which is apt to settle on the heating surfaces and so taint the incoming air. A type of air heater in which excellent use is made of the insulating effect of the incoming air is shown in Fig. 124. In this, the stove may be in the basement with a grating in the floor of the hall or apartment immediately above. The stove is provided with a double air jacket, the grating being divided in such a way that the cold air, at floor level in the apartment above, passes through the outer openings into the outer jacket, to start warming as it falls (because it is cold and therefore heavy). At the bottom it turns into the inner air jacket, close to the combustion chamber, where it absorbs heat rapidly, expands, and rises with increased velocity, passing through the centre openings of the grating to diffuse in the hall or room above. Such an air-heater will work very economically without any lagging at all, except that provided by the double air jacket, but an insulating jacket is no doubt an advantage in keeping the boiler-house cool and preventing the waste of heat where it is not needed.

Air heaters of this type, placed under the hall, will provide warm air for the whole of a small house, if suitable inlets and outlets are provided in the apartments opening into the hall, or into the main staircase leading from it, but, of course, such an arrangement could be considered as auxiliary only, open grates or similar units being used as well. A one-storey building like a church or concert hall can be warmed very effectively by such a a unit, or by several such units if the building is a large one, while ventilation can be introduced at the same time by inserting a fresh air duct, controlled by a valve or damper, leading to a grating in an outer wall.

If the warm air outlet from a stove of this type is connected to a vertical trunk with branch ducts, leading to the various rooms of a fairly small compact building of three or four floors, there is no doubt convection currents would provide sufficient motive force to impel the warm air to its destination, but for an equal number of rooms more widely spread in a building of one or two floors only, a fan on the fresh air intake would ensure the air being driven into the rooms concerned and make it possible to get

complete control. by means of dampers or "hit and miss" gratings at the delivery points. It would. in fact, have become a miniature plenum ventilation plant without the elaborations of air conditioning.

Natural and Artificial Lighting. To be sanitary in the fullest sense of the word, a building must not only be well warmed, it must also be well lighted, both naturally and artificially. Even in olden times this fact was recognised, for one finds the following in the writings of Lucar, who lived in Elizabeth's time: "For Heaven's sake make all the rooms of youre house lightsome, of a convenient height and of a laudable largenesse. Beware you do not sleepe in a close place."

Natural Lighting. In the very earliest times of which we have details, glazed windows were unknown, the ancients providing wide, low openings to their one-storey houses, just under the eaves of the roof, high enough up in the walls to ensure privacy, the openings serving for both light and ventilation. This arrangement influenced the whole of their architecture. The ancient Egyptians used similar openings with gratings. One often finds windows referred to in the Bible, but there are seven words in the original writings which have all been translated "window". The windows in the ark of Noah were, according to correct translation, translucent, and are believed to have been filled with an arrangement of polished oyster shells. In the Book of Judges, windows with movable lattices are definitely referred to. The use of glass for glazing windows was known to the Romans, though talc was more largely used by them, while they also used sheets of oiled linen and thin plates of horn. One reads of the Emperor Caligula neglecting the duties of state to supervise the reconstruction of his windows with sheets of glass instead of sheets of talc. The excavations at Pompeii have brought to light the fact that glass windows were used in the better houses, while the baths had windows glazed with plate glass ground or obscured on one side to prevent people seeing through.

Various materials have been used for covering window openings. Thus, the Greenlander of to-day fills them with the maws of halibuts. The Saxon used oiled linen, panels of horn, and lattices of wicker work or thinly cleft oak. The Romans, during their occupation, do not seem to have introduced the use of glass for this purpose in Britain, and the earliest mention of glass windows in England is in respect of the glazing of the windows of a church in York in 627 A.D. By the time of Chaucer (14th century) its use was more general, and in his "Dreme" he thus describes his bedroom:

With glas
Were alle the windowes well yglazed.

His poems also show that the casement window was in use then. Till the time of Henry VIII, however, the use of glass did not become very general, and one reads, in the records of Alnwick Castle, that the glazed windows were taken out and put in a place of safety while the family were away!

Early Sash Windows. The sash window was introduced about the time of the Great Fire of London, the upper one being fixed and the lower one raisable, being kept up by a system of notches and catches. The sash window with the sashes hung by means of cords and weights, as now used, is believed to be a Dutch invention, and was certainly introduced into this country with the arrival of William of Orange.

Modern Natural Lighting. Present-day natural lighting is provided by glazed windows, lantern lights, skylights, fanlights, rooflights, glazed doors, and sometimes even by wall panels constructed of glass bricks.

Every habitable room should have a window opening into the external air, which is usually insisted upon irrespective of any other ventilating openings which may be provided. Factories, workshops and sometimes other buildings as well, are often provided with diffused natural light by means of roof glazing on the northern slopes of the roof while the southerly slopes, which might let in too much direct sunlight for the good of the work in hand or the comfort of the workers, are clad with slates, tiles or corrugated asbestos. Local by-laws often prescribe a minimum window area, for domestic buildings, not less than one-tenth of the floor area. This figure is the minimum allowance to satisfy the by-law, and not of necessity the ideal. Most architects look upon one-seventh of the floor area as a more satisfactory allowance, but it should be remembered that large windows entail greater expense in warming the building.

Placing of Windows. A further usual provision is that a minimum amount of the window area, equal to one-twentieth of the floor area, shall be made to open. Windows should be very carefully placed in designing a house. They should extend as nearly to the ceiling as possible and should be in the middle of a wall. If placed at one end of a wall, the room will not be nearly so well lighted as if the window is in the middle of the same wall.

Vita Glass. Most windows are glazed with ordinary sheet glass, but for nurseries, sanatoriums, hospitals and schoolrooms, "Vita" glass, or some similar type, made from a formula to pass as many

as possible of the ultra-violet rays, may be worth the additional expense.

Pilkingtons Double Glass. A very useful type of glass for conserving heat in the house is provided with spacing pieces at the edges providing a very narrow air-cavity and passe-partouted round the edges. It will fit into the rebates of most normal glazing bars intended for single glass. The two sheets of glass are hermetically sealed at the edges, so there is no fear of dust or vapour in the interior clouding the vision and the "U" transmission factor is about half of what it would be for "single" glass.

School Lighting. Schools should receive special attention to their lighting, and most education authorities insist on about double the usual allowance of window area, with the light designed to fall from the side of scholar and teacher alike, and for preference from the scholar's left, so that no shadow is thrown on the exercise book when writing.

Plate and Other Types of Glass. For very large windows and first-class work plate glass must be used. Where the glass need not be transparent it is possible to get increased light by using a highly refractive glass such as muranese or prismatic. Both have a raised pattern on one side of the sheet, and this should be on the inside of the room. In the case of prismatic glass the pattern takes the form of straight V-shaped grooves over the whole surface; these should be placed horizontally in order to refract the light and divert it into the room instead of letting it fall on to the floor just inside the window. This sort of glass is often used for increasing the light in dark offices, but it is little used in domestic buildings, on the ground of appearance. For offices in narrow streets, outside reflectors are frequently used, but these are not very suitable for domestic work.

Reflective Surfaces. If the window opens on to a small enclosed yard, or there is a wall opposite and not far from it, the light may be increased by facing the wall with white glazed tiles, or by white-washing it. White glazed surfaces, when used externally, rapidly collect dirt, and unless kept clean are no more efficient than white-wash. Wherever the latter is used it should be renewed annually, and the former should only be used where it can be readily cleaned. Where there is a basement to a house with a forecourt, the area in front of the basement windows is often too narrow. The light may be increased by sloping back the area wall, in a direction away from the window, and lining it with tiles or whitewashing it. Where there is no forecourt, areas in the front of basement windows

are covered with gratings. These should be made up of narrow, deep bars, placed at right angles to the face of the building. If placed in a direction parallel to the face of the building, they obstruct far more light.

With new buildings, the architect must acquaint himself with any local by-laws which may be in force as to the open space to be left at the back and front of domestic buildings, while the requirements of Public Health Acts, The London Building Acts (for the London area) and the Town and Country Planning Acts must be consulted. Some brief notes of these will be found in Chapter I and in the chapter on "Legal Notes", while for greater detail the acts themselves should be consulted.

Artificial Lighting. We now come to the consideration of the means of providing artificial light, which may be roughly summarised as candles, oil lamps, gas and electricity.

Most people think of candles as means of decorating a birthday cake or of ornamenting the table on festive occasions, but they are still the means by which we measure the strength of light, even the most modern types of illuminant being tabulated as having so many candle-power. One does not notice much vitiation of the air if they are used in this casual way, but if a room were lighted with exactly the same *quantity* of light by each of the various methods, the comparative vitiation of the air would be as follows: Candles, 1; oil lamps, 0·7; ordinary gas burners, 0·45; incandescent gas burners, 0·27; and electricity (provided the ordinary gas-filled bulb is used), 0.

Oil lamps. Oil lamps are still largely used where electricity and gas are not available. To be of the greatest efficiency they should be of good construction and carefully attended to. To get complete combustion and freedom from smell, there should be proper means of regulating the air supply to the flame, and a chimney of proper height. The receptacle for oil should never be allowed to get quite empty, or an explosive mixture of air and oil vapour may be formed. On the other hand, the receptacle should never be filled too full, or the oil may run out and be set alight. Paraffin lamps are of two principal types, viz. those which produce a blue flame to heat a ramie-thread mantle to incandescence and those which produce a white fish-tail or circular flame as the illuminant direct. Mantle lamps are far more efficient and therefore produce less pollution for a given unit of illumination. In using oil lamps, the impurities given off are carbon dioxide, water vapour, free carbon and oily vapour.

Coal Gas. Ordinary coal gas is still used a good deal for lighting

streets and buildings. It can be said to consist of three classes of constituent: the illuminants, the diluents and the impurities. The power of illumination is derived from unsaturated hydrocarbons, which would cause smoke in the absence of diluents such as hydrogen, saturated hydrocarbons, such as methane, and carbon monoxide, etc. The impurities consist of small percentages of carbon dioxide, sulphur compounds not effectively removed in the process of purification, etc.

Calor Gas. Calor Gas has already been described when dealing with heating. It is quite suitable for lighting also in any situation where neither electricity nor coal gas is available. As an alternative to electricity it does not seem to have the advantage of cheapness for lighting purposes that it has for heating and cooking.

Water Gas. Water gas is produced by passing steam through incandescent coke or anthracite coal, vaporised mineral oil being added to the resulting product. The fittings and pipes should be thoroughly gas-tight if this gas is used, as it contains a large proportion of carbon monoxide, a very dangerous gas to breathe.

Impurities. Generally speaking, the impurities given off by the combustion of gas include carbon dioxide and monoxide, ammonia and sulphur compounds, and water vapour.

Coal gas is generally burnt, mixed with atmospheric air, in a heat-giving blue flame, in such a way as to heat an asbestos gauze or ramie-thread mantle to incandescence. The mantle may be upright or "inverted" the latter throwing less shadow downwards. The old-fashioned "batswing" or "fish-tail" burner is obsolete for coal gas, though an adaptation of it is still used for acetylene gas, which burns with a whiter flame. In the fish-tail burner, the main source of light was the burning, in the gas, of tiny particles of carbon which were carried along the pipes in suspension.

Acetylene Gas. Acetylene gas is produced by the action of water on carbide of calcium. It gives a very brilliant light, making the mantle a superfluity. It is used for country houses without the advantage of public services such as gas and electricity, but is not in very general use owing to the extreme care required, and Calor gas is preferable in such cases. All pipes and fittings must be thoroughly gas-tight, as a mixture of a very small proportion of acetylene and air is explosive.

Air Gas or Petrol Gas. Opposite in nature to that just described is what is known as air gas, in reference to which it is claimed that a burner might be turned on all night, unlighted, in a bedroom

without danger. It consists of a mixture of air and petrol vapour, a very small percentage of the latter being needed to produce an illuminant. Small plants on this system are obtainable for country houses.

Electricity. The development of the electrical grid system has extended the advantages of electricity to remote parts of the country. The presence of a grid line will, however, not always make a supply available in its vicinity at a reasonable cost; for these lines are at a high voltage, to diminish losses in transmission, whilst it would be unsafe to supply houses at a high voltage. Consequently the installation of a transformer is necessary to make the supply available locally, and the cost of this, and of the low-tension cables, will be justified only where a considerable number of consumers will take a supply.

Electricity is undoubtedly the most satisfactory artificial illuminant for all-round use at present available.

Gas-filled Lamps. For domestic purposes the form of lamp generally used is a glass bulb filled with argon and containing a wolfram or tungsten filament which, owing to its resistance to electricity, glows to incandescence when a current is passed through. Bulbs fitted with coiled coil filaments (owing to the extra length) are the most efficient in this class. Lamps with carbon filaments and those of vacuum type use considerably more current and are seldom used now. Apart from the type and the efficiency of lamps themselves, their disposition about the room has to be considered. Pendants with one or more lights hanging from the centre of the ceiling give a good general illumination. Wall lights, either by themselves or in conjunction with ceiling pendants, often fit in better with schemes of decoration and provide localised illumination. Where an even lighting is required, without shadows or reflections, concealed lighting has much to recommend it. For this purpose "strip" lighting of the fluorescent type, referred to later under "Gas Discharge Lamps", is very commonly used.

Where special concentration of light is required table and desk lamps with fixed or flexible supports may be recommended, while the hinged type of fitting may be adopted to give a close concentration of light where the general appearance is of less importance than utility.

Recommended Values of Illumination. The values of illumination for different types of building or the needs of various parts of the house or for sundry occupations in the office, factory or elsewhere may be had by reference to the Code of Recommended

Values of Illumination issued by the Institution of Electrical Engineers.

As the bulbs are hermetically sealed, no impurity can be passed into the air, and they must rank as the most sanitary illuminant we have, as well as the most convenient.

Arc Lamps. Electric arc lamps (depending upon the incandescence of a stream of carbon particles, as an arc of current jumps a gap between two carbon "needles") are less desirable for interior lighting, as a good deal of carbon monoxide and a small percentage of nitric acid is given off. They are used to some extent for street lighting, railway stations, large exhibition halls and the like, where they will be unlikely to affect ventilation or to cause discomfort from the glare.

Gas Discharge Lamps. "Gas discharge" lamps are a great improvement on arc lamps for street lighting and large halls, and have made the arc type practically obsolete. Being in sealed glass containers, they cannot affect the atmosphere in any way. Fluorescent tube lighting is of this class, and is now used extensively in shops, offices and in the kitchens of private houses. For certain types of building and for those parts of the private house where a soft light is required, concealed lighting in which the fluorescent tubes are hidden behind an architrave or other feature find much favour. The tubes are filled with various gases or vapours, according to the colour of the light desired, and an electric terminal is attached at each end in such a way that a high voltage electrical discharge through the gas causes a luminous glow.

For street lighting the tube or gas chamber is short and the gases used give varying qualities and intensities of light.

In the early experiments the light produced, while very penetrating, had a very unpleasant effect on the appearance of persons coming within its range, but recent forms give a very useful and penetrating light, which, while cold in its effects, is not otherwise unpleasant.

Candle-power. The "candle-power" by which the brightness of a lamp is measured is the quantity of light given by a properly trimmed spermaceti candle burning 120 grains of wax per hour. In order that it may be properly measured and compared, it is necessary to be at a definite distance from the illuminant, because light, like heat, diminishes in the ratio of the square of the distance from the illuminant and for this reason the "foot candle" is introduced, which is the amount of light given by a 1 c.p. light to a surface held at a distance of 1 foot from it and perpendicular to the centre ray of light.

Instruments for Measuring Candle-power. The candle-power of a lamp is measured by comparing its illuminating power with that of a lamp of known candle-power, the instrument used being known as a "photometer", the standard testing lamp being a "pentane" lamp.

The most commonly used photometer is the "flicker photometer", in which a rapidly moving prism is made to reflect alternately the light of the lamp to be tested and the standardised light. If the lights are of unequal intensity, the beam reaching the eye will flicker, while, if they exactly match, they will merge and the joint beam will appear perfectly steady.

The Lumen. As the object of lighting is usually to illumine a given surface or space, an even more useful unit is the "Lumen", which is the amount of light necessary to illuminate 1 square foot of surface with an intensity of illumination of 1 foot candle.

Measurement of Daylight. The daylight illumination of rooms is generally measured, not by the absolute quantity of light received (which must, of necessity, be very variable), but by the ratio or proportion of unobscured sky visible in various parts of the room and by the distance from the window.

The "Sill Ratio". In this connection the "Sill Ratio" is the ratio or percentage of the quarter-sphere of sky which would be visible at the sill of a window, set in a wall of unlimited height and length, the horizon being taken as in the horizontal plane of the window sill.

Daylight Factors. The "Daylight Factor" is an alternative unit and is the percentage of the hemisphere of sky which would be visible on the roof of a very large flat roofed building, the horizon being taken as in the horizontal plane of the flat roof.

Various instruments have been devised for measuring the sill-ratio or daylight-factor, but Swarbrick's "Daylight Factor Theodolite" is perhaps the most precise instrument for the purpose.

The units and the instruments for measuring them are employed chiefly for assessing the damage to light caused (or likely to be caused) by obstructive buildings in "Easement of Light" cases, but they have occasionally been employed for measuring the percentage of daylight available for industrial purposes, apart from any question of easements or their infringement.

It should be noted that it is now possible to compute with fair accuracy, direct from the drawings, the daylight factors for all normal conditions of roof and wall lighting by the use of the

special protractor devised by the Department of Industrial and Scientific Research and described in Technical Paper No. 28 published by H.M.S.O., price 4d.

For more detailed descriptions of the methods and apparatus used for measuring natural and artificial illuminants, the reader is referred to treatises devoted entirely to illumination.

CHAPTER VI

The Building—Its Water Supply

Composition of Water. Water is a chemical compound of hydrogen and oxygen, each molecule consisting of two atoms of the former to one of the latter; by weight it consists approximately of oxygen 89 per cent. and hydrogen 11 per cent. As found in nature, it is almost impossible to obtain water free from impurities, which take the following forms: dissolved and suspended inorganic and organic matters, and micro-organisms.

Impurities. The amount of dissolved inorganic matter in a sample of water depends very largely on the nature of the soil, through or over which it has passed. The chief mineral impurities are lime salts, chiefly the bicarbonates and sulphates; others are bicarbonate and sulphate of magnesium, chloride of sodium, iron salts, and silica. The salts of metals are also found, chiefly those of lead and copper, the first named being poisonous and the more common. The presence of lead in water is generally due to its being taken up by acid water, or water containing a large amount of nitrates and no bicarbonates, in passing through lead pipes or when stored in lead-lined cisterns. Water containing the smallest quantity of lead is dangerous for domestic purposes, as its effect is cumulative, so small a proportion as 1 part in 700,000, or 0·1 grain per gallon, being sufficient to set up lead poisoning in the system of a person who is in such a state as to be readily affected. The hardness of water is due to salts of lime and magnesium, but a moderate hardness is not harmful.

Suspended Inorganic Matter. The suspended inorganic matters are chiefly brought into the water in the form of impurities washed from the air by rain, or taken up in its passage over or through the soil. Examples are minute particles of sand, chalk, marl, oxide of iron, etc., all of which will settle and form a sediment when the water is at rest. They frequently cause colour but are not necessarily harmful to it, and are easily removed by filtration.

Dissolved Organic Matter. Dissolved organic matters may be of either vegetable or animal origin. The former are not necessarily harmful, but the latter, consisting of ammonia compounds and matters arising from putrefaction, are always dangerous. Thus water from a peaty soil may be wholesome, but the presence

of animal organic matter often indicates sewage pollution, and any water containing traces of it should be rejected, unless it can be suitably treated.

Suspended Organic Matter. Water containing suspended organic matter is also always suspicious, as it may be accompanied by the presence of disease germs. Examples of suspended vegetable organic matter are woody fibre, pollen, starch cells, and fungi, and of animal matter, hairs, dead insects and other minute animals, and possibly scales from the skin of diseased persons.

Micro-Organisms. Micro-organisms may be of either a harmful or a hurtful type. They are so minute that their classification is a matter of difficulty, but it is known that polluted waters abound in germ life, and therefore the greater the number of bacteria present, the more suspicious the water is.

Quality of Water. A good water for domestic purposes should fulfil the following conditions: It should be practically colourless and clear, free from sediment, and sparkling and pleasant to the taste. It should have no smell, be soft to the touch, dissolve soap easily, and be sufficiently aerated. It should be free from organic pollution and contain no more than a small number of bacteria.

Simple Tests of Water. Some of these requirements can easily be verified by simple tests; others by experts only. The rough tests which can be applied by almost anyone will first be described.

Palatibility. Palatibility is purely a matter of tasting. Smell is also a matter for the senses, but one must go further. Take a stoppered glass bottle of large size, such as that known as the "Winchester quart", and holding about half a gallon. Wash it out with a weak solution of sulphuric or hydrochloric acid and rinse it out repeatedly with the water to be tested. Immerse the bottle in the water, allow it to fill to within about 2 inches of the neck and securely stopper it. Expose it to light and warmth for not less than twenty-four hours, to see if vegetation is set up or putrefaction occurs. On removing the stopper, this will be discernible by smell, and water not bearing this test should be rejected or suitably treated.

Colour. If water is tinged with colour, it is generally due to dissolved organic matter, such as peat or decayed leaves, though it may be due to iron, in which case it is not necessarily a bad water, although one to be avoided if possible. The colour cannot as a rule be judged merely from filling a tumbler. We should use two glass tubes, each about 24 inches high and 2 inches in diameter. One should be filled with distilled water and the other with the water to be examined. If they are placed on a white tile or sheet

of white paper, a comparison of colour can easily be made, when viewed from above and the tube lifted about 2 inches from the tile. If found to be tinged with colour, a rough test can be made in order to see if the cause is organic matter. Add a drop of Condy's fluid to a glass of the water, which should thereby be turned pink. If the pink colour remains, all is well as regards this point, but if the colour be bleached, the presence of organic pollution is indicated. The presence of chlorine (as chlorides) may be detected by adding a small quantity of nitrate of silver and dilute nitric acid. Small tabloids are obtainable for this purpose. If chlorides are present, the fact will be indicated by a haziness or by a more or less white precipitate, 1 grain per gallon giving a haziness, and as much as 10 grains per gallon a considerable precipitate. The presence of chlorides in considerable quantities is not sufficient in itself to cause one to condemn a water. It may be due to urine or other such animal contamination, or it may be due to the water having passed through or over rocks containing chlorides; it may also be due to sea-spray or to seaweed used as manure. The cause of its presence should therefore be investigated as far as possible and perhaps a geologist consulted.

If the above rough tests clearly indicate serious pollution the source of supply might as well be abandoned at once, if any other source is available; otherwise it would be necessary to install expensive filtration and sterilisation apparatus, as will be explained later.

Analytical and Biological Tests. If the water passes these rough tests satisfactorily, it should be submitted to expert investigation by an analytical chemist and preferably by a bacteriologist also. The manner of taking the sample for an analyst is important. It should be of sufficient quantity and accompanied by the fullest particulars. A "Winchester quart" bottle should be obtained, and cleaned and rinsed out as before described. It should be filled to the neck, the stopper being firmly put in and covered by a strip of leather or cloth, which should be tied round and sealed. If a glass stopper is unobtainable, a cork may be used, but it must be a clean, new one. The bottle should be labelled with brief particulars and the date, and at once forwarded to the analyst with the fullest particulars, such as the nature of the source and reason for requiring the analysis. For example, if it is a case of illness, the nature of such illness. In the case of a supply from a well, the approximate depth, position in relation to drains and cesspools, if any, and any other possible source of pollution should be stated. The analysis should be commenced within forty-eight hours if

possible. Water supplies require examination from time to time. Occasional pollution may be due to a spell of heavy rainfall, bad condition of filters, or in the case of a house, defective cisterns and fittings.

Taking Samples. For the bacteriologist a smaller bottle is used, generally of about 8 to 12 oz. in capacity, fitted accurately with a ground glass stopper. This should be thoroughly sterilised before use. The stoppered bottle should finally be made secure by a piece of oiled silk tied over the stopper. It is also necessary that it should be kept very cold and examined with the least possible delay. Bacteriologists use special bottle cases for the transmission of samples. The bottle fits into a tin-lined receptacle, surrounded by another casing for holding ice, this in turn being surrounded by a layer of asbestos, and the whole fitting into a wooden box fitted with a lock.

If the sample is to be drawn from a pump or tap, the nozzle of the pump or tap must be thoroughly cleansed, and then flamed with a plumber's blow-lamp, or else wiped with a large wad of cotton wool, soaked in methylated spirit.

Reading the Analytical Chemist's Report. The report of the chemist is sometimes rather too full of technicalities to be readily understood by the surveyor, but there are certain guiding points which may with advantage be referred to.

A large quantity of "albuminoid" ammonia, together with large amounts of "free" ammonia and chloride, points to sewage pollution. This will be confirmed if the bacteriologist finds large quantities of those bacteria which are characteristic of animal pollution.

A large quantity of "albuminoid" ammonia, with only a little "free" ammonia and a little chloride, points to vegetable contamination only. This will be confirmed if the bacteriologist finds few of the bacteria which are characteristic of animal pollution.

In addition to the ammonias and chlorides, nitrites and nitrates may be present. Nitrites and nitrates are always found in sewage effluents after treatment of the sewage in bacteria beds. Nitrites indicate that there has been a quantity of organic matter present, that this has been undergoing oxidation, but that the process is not yet complete. Nitrates indicate that oxidation of such organic matters is complete. If a water contains nitrites and nitrates the report of the bacteriologist will again be of great interest, as the bacteria originally present may still be present in very large quantities.

The most useful information that can be derived from a chemical

analysis is from the determination of the quantity of albuminoid ammonia present, and the amount of oxygen which will be absorbed by the water when kept at the standard temperature of 80° Fahr. for the standard time of four hours. Chemists will normally approve a water if it has not more than 1 or 1½ parts of albuminoid ammonia in ten million parts of water, and if it will, at the same time, not absorb more than one part of oxygen per million of water.

Reading the Bacteriologist's Report. The report of the bacteriologist is of a character even more technical than that of the chemist. He is able to distinguish the possible presence of "pathogenic" (harmful) bacteria in a sample of water, and to estimate the quantity of both the pathogenic and non-pathogenic varieties, and to draw conclusions as to the degree of pollution to which the water has been subjected. The normal procedure in water examination is to look for and count a group of bacteria known as "Bacillus Coli", an intestinal organism which is to be found in immense quantities in the excretions of all animals, healthy or otherwise, and which is able to survive for long periods in water at ordinary temperatures. The importance of this group lies in the fact that its presence in a sample of water clearly indicates contamination from animal excretion and that all the water-borne diseases affecting man, such as cholera, typhoid, para-typhoid, dysentery, etc., are transmitted from the intestines of animals. To search for the specific bacilli of the aforementioned diseases is too difficult an undertaking to be practical in routine water examination, though it might be attempted in special cases, as where a disease has broken out locally.

It may be taken as proved fact that a natural water which contains no Bacillus Coli cannot contain any dangerous number of any disease-producing bacteria, and that a polluted water which has been so treated as to destroy all Bacillus Coli is as incapable of producing disease as the purest natural water.

It is usual to look for Bacillus Coli in samples of 0·1 c.c., 1 c.c., 10 c.c., 50 c.c. and 100 c.c. If the bacillus is present in 50 c.c. the water is viewed with suspicion; if present in 1 c.c. it would be regarded as dangerous.

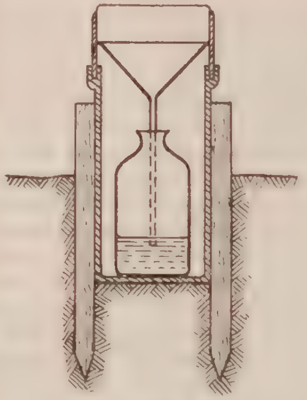
Water Treatment. A water which is found not to comply with the above standards of chemical analysis and bacteriological examination would not necessarily be discarded forthwith; no better water may be available at a reasonable cost. A careful examination of the source of the supply and its surroundings should be made with a view to the removal of sources of pollution,

after which the water may be tested and examined again. If this proves fruitless, the water, if not hopelessly polluted, may be rendered safe by filtration, accompanied probably by sterilisation, by methods which will be described later.

Quantity of Water Consumed. It will be obvious that the quantity of water required per head of population per day depends on a variety of circumstances. Thus, in a village, it is often limited to that needed for cooking, drinking, clothes washing and house cleaning, and a small amount for waste. The use of water-closets is less general in villages, earth-closets and privies being used instead. Bathrooms, also, are less general, unfortunately, in country cottages, and so there is not a great demand for water on that score. Similarly, there is no question of flushing drains and sewers, nor are there any public conveniences to be automatically flushed, nor manufactories to be supplied with water for conversion into steam or used in trade processes. It would appear reasonable therefore to suggest the following figures: for country cottages without baths or water closets, about 5 gallons per head per day; for a village, about 12 to 15 gallons per head per day; for a residential town, about 20 to 30 gallons; and for a large manufacturing town about 35 to 50 gallons per head per day.

The original source of all available water is the rainfall. Part sinks into the ground to form underground supplies, part flows off the surface to form streams, and part evaporates. The amount of rainfall varies greatly in different places; thus on the East coast of England it averages about 20 inches per annum, on the South coast about 30 inches, and in a few places in the Lake District it is over 100 inches per annum. The amount of rainfall is measured by means of rain gauges.

Rain Gauges. The sketch, Fig. 133, shows a vertical section through a common form. It is constructed principally of copper, and consists of (1) a cylindrical body; (2) an inlet, fitting into a groove round the top of the body, cylindrical at the top, with a bevelled edge, and in the form of a funnel at the bottom, terminating in a tube; (3) a bottle or other similar receptacle; and (4) a separate measuring glass graduated to read inches of rainfall and applicable only to the gauge with which it is supplied. The instrument is secured to the ground with small oak stakes and is fixed with its mouth about a foot above the ground, to prevent water splashing in. It is made of various diameters, but that in most general use has a diameter of 5 inches at the mouth. Rain gauges must be fixed in an open space, clear of any obstructions such as trees or anything likely to prevent the direct access of



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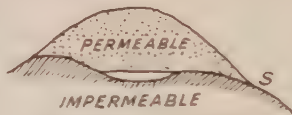
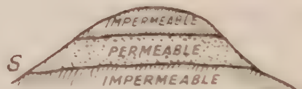
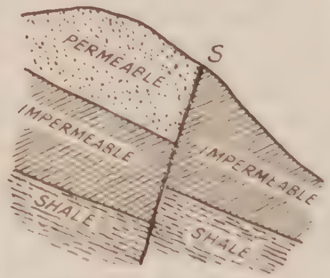


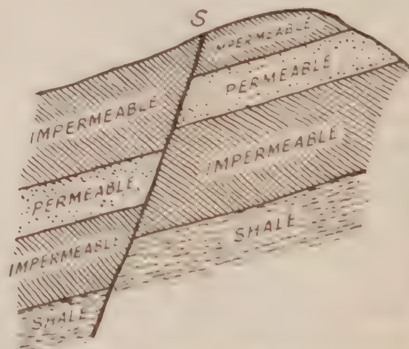
SURFACE SPRING
134



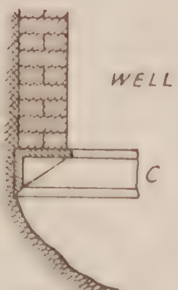
DEEP SEATED SPRING
135



SURFACE SPRING
136



DEEP SEATED SPRING
137



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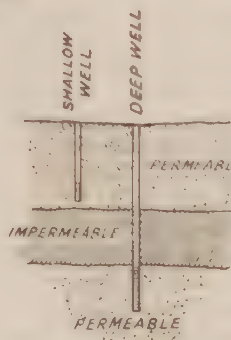

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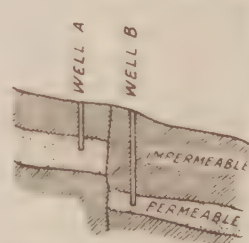


140

rain. In dealing with a large area, a series of gauges would be used, scattered about the district; thus in the huge water supply scheme of the Derwent Valley Water Board, for the supply of Leicester, Derby, Sheffield and Nottingham, the catchment area of which scheme is nearly 50 square miles, fifty rain gauges were used, or approximately one per square mile. This is generally regarded as sufficient to enable one to deduce a sound average.

Sources of Water Supply. Let us next consider the sources from which water is obtained, dealing with this point under two headings, (1) geological, and (2) practical.

Alluvium often rests on an impervious bottom, on which water will collect, and which can be reached by sinking a well. In some parts of the Pleistocene formation a layer of middle drift is found between two boulder clays, in which case wells sunk through the upper clay will provide a hard water. The Pliocene can be bored in many places for water. In the case of the Oligocene, the sands of the Osborne beds contain hard water, and water is invariably found at the surface of the Barton clay. With the Eocene formation, the Bagshot sands, where they rest on the Bagshot marls, provide a supply for wells. The London clay is impervious, but the Oldhaven, Woolwich and Reading beds, and the Thanet sands contain much sand and gravel and are full of water in many places.

Chalk Strata. The chalk around London forms a fine source of supply, the water being held up by the impervious strata beneath. If the London clay is bored through the water will rise nearly to the surface. The Upper Greensand contains a good deal of water but its area is limited. The Lower Greensand, underlying the Gault, is a good water-bearing stratum. The Hastings Sand furnishes a water of a somewhat chalybeate nature, Tunbridge Wells being situate upon it.

Oolite. The Upper Oolite is a poor water-bearing stratum, but the Middle Oolite furnishes a good supply and wells are largely sunk into it; the Lower Oolite also yields a good water in places. In the case of the Trias, the lower portion of the Keuper series contains porous beds with considerable water, supported on seams of compact marl. Springs occur at the outcrop and plenty of water is obtainable by boring, but it is very hard.

The Bunter Sandstone. The Bunter sandstone is the most important water-bearing stratum in England, except the chalk with greensand. The yield is largely due to the permeability of the strata, and the wells of Manchester and Salford alone yield

6,000,000 gallons per day of clear water, drawn from an area of not more than 7 square miles, largely covered with buildings, streets and boulder clay. Possibly much of the water percolates from the Rivers Irwell, Irk and Medlock, which traverse the strata, but, if so, the sandstone is a wonderfully effective filter, since the the rivers named are very foul. One spring from this source, the Wall Grange spring near Leek in Staffordshire, yields, 3,000,000 gallons a day.

Permian Formation. The Permian formation also contains much water in its lower beds when they immediately overlie those of the carboniferous series. The Coal Measures contain alternating beds of grits and clay, the former being full of water. The Millstone Grit, where resting on shales, also gives a good supply. The Devonian and Old Red Sandstone rocks frequently furnish springs. The Silurian, Cambrian and Igneous rocks are only suitable for large collecting areas of surface water.

Analysis of Sources. The sources from which water is usually obtained from a practical point of view, are (1) upland surface water, collected from large uncultivated tracts of land; (2) streams and rivers; (3) springs; (4) wells; and (5) rain water collected from roofs and other collecting areas.

Springs. Springs are derived from that portion of the rainfall which has sunk into the soil. They may be divided into two classes, (1) surface springs, and (2) deep-seated springs. The water falling on the surface will percolate downwards until it is stopped by an impervious layer. It will then issue at the lowest point of the porous stratum, usually on the side of a hill or cliff. Fig. 134 shows such a case. It represents a section through a hill with a permeable stratum overlying an impermeable one. The surface water will percolate downwards till its descent is arrested, when it will issue at the point S on the hillside in the form of a surface spring. Fig. 135 shows another such case. In this a permeable stratum occurs between two which are impermeable, the former coming out to the surface, or outcropping, on either side of the hill. Surface water will pass over the upper impermeable layer, and with that collected on the exposed part of the permeable will percolate through the latter, issuing at the lowest point S in the form of a deep-seated spring.

Fig. 136 shows a case where the continuity of the permeable stratum is interrupted by a fault. The water in such a case will collect in the permeable stratum and overflow in the form of a surface spring at the point S.

The water from a surface spring is unlikely to be as pure as

that from a deep-seated spring, owing to the water in the latter case having filtered downwards to a greater depth. Fig. 137 gives a section showing one example of a deep-seated spring. Owing to a fault or dislocation of the strata, the water in the permeable stratum is obstructed in its downward flow and finds an outlet upwards through the line of fault, issuing at S.

Springs, if they happen to be available, give a useful source of water supply for isolated houses in the country or small isolated blocks of cottages. The more deeply seated it is, the better, generally speaking, will the water be. Thus, in the case shown in Fig. 137 it will be seen that the water is less liable to surface contamination than in those shown in Figs. 134 and 136, owing to its filtering through greater depths. Sometimes the outlet area is rather large, but this can be overcome by forming a channel, or a small gallery, in the hillside to tap the water as it reaches the surface. Springs do not normally provide a sufficiently constan source for the supply of towns, but there are a few cases in which towns are supplied in this way, notably Bath, Malvern, and Lancaster, while part of London's supply comes from springs in Hertfordshire, a conduit about 40 miles long having been utilised by the New River Company for the purpose of conveying it.

In supplying houses in the country, a spring may sometimes be obtained at such a height as to supply a storage tank by gravitation. Such tanks are usually made of sufficient size to contain from about three days' to one week's supply. If the spring is large, a ball-valve inlet should be used. The tank should be covered and ventilated and provided with an overflow. Such tanks can be formed of concrete backed by clay puddle and rendered inside in cement mortar. If the water is not of the best, it may be made to pass through a sand filter before reaching the tank, or, if it is not so filtered, pressure filters should be used on the taps supplying drinking water. These filters will be fully described later.

If the level of the available spring does not permit of supplying the storage tank by gravitation, the water must be pumped up to a storage tank situated in the highest part of the house.

Wells. Water is also obtained from wells sunk into the underground water to a level below that at which it would issue as springs. Wells are classed as shallow and deep respectively, and it is important to note that these terms, as used in this connection, have no direct reference to depths in feet. Thus, a shallow well may be a greater number of feet in depth than a deep one, the term shallow meaning that the source of supply is the subsoil

water, while the supply for deep wells is derived from a water-bearing stratum beneath an impermeable one and often at a great depth.

Shallow Wells. The water from shallow wells is always open to suspicion, owing to the liability of pollution from defective drains and cesspools. The underground water is always moving, and by its lateral motion or by its rise and fall in times of heavy rainfall or drought, may place the water in the well in direct communication with sewage-sodden soil. In an attempt to obtain a pure supply from a shallow well, therefore, the well must be as far as possible from any likely sources of contamination, with the dip of the strata towards any neighbouring cesspools, lined (or "steined") with brickwork (as shown in Fig. 138), concrete, stoneware tubes, or iron cylinders, be covered over and a permanent pump fixed. The old-fashioned "draw" or "dipping" well is not permissible under any circumstances, if only owing to the possibility of polluting matters finding their way in at the top.

Steining. There are many ways of steining a shallow well with brickwork; three will be described:

If the ground is reasonably firm it should be possible to excavate successive depths of 3 feet or 3 feet 6 inches, and then to timber each length immediately with poling boards, walings and struts, until a depth is reached several feet below the lowest level of the subsoil water, the excavation being kept dry by continuous pumping. When the bottom is reached a 6-inch diameter pipe is sunk vertically in a hole to act as a sump for the pump and around it is built a floor of concrete. The walls are then built up, timbering being removed as required. The brickwork for some distance up from the bottom will have open vertical joints, to allow water to pass in; above this level it will be solidly built in cement mortar, with clay backing, to exclude surface water. At the top the diameter is reduced by corbelling to about 2 feet and the opening covered by a stone slab with lifting ring, the top of the slab being about 1 foot above the level of the ground, whose surface should be concreted around the cover. A permanent pump is fixed and the temporary sump in the floor concreted in.

The second method, like the first, is possible only when a reasonable depth of soil can be excavated without setting timbering. Excavation is carried down as far as is safe and a circular kerb of oak or elm, 9 inches wide, is laid to form a support for the wall. The wall is then built up in cement mortar and backed with clay puddle, 6 inches thick. Holes are then dug in the ground below

for the insertion of inclined struts for the temporary support of the walling, with their lower ends resting on solid wooden foot-blocks near the centre of the well and with their upper ends wedged under the wooden kerb. Excavation then proceeds down to the level of the foot-blocks, where another kerb is laid. Brickwork with clay backing is built up upon it, as before, to a level as close as possible to the kerb above, after which the space between is wedged tight with pieces of slate and cement mortar. In building these lower lengths gaps must be left around the inclined struts, but when the brickwork is sufficiently set to carry the weight, the struts are removed and the remainder of the brickwork filled in. Successive lengths follow in similar manner, but the last length or two will have open vertical joints and no clay backing.

The third method is one which can be used even where the soil is insecure, so that it would not be possible to excavate any appreciable depth without timbering. Its disadvantage is that it is not possible to form a clay backing to the steining, so that percolation of surface water down the outside of the wall is more likely than where the other methods are used. A circular iron kerb, with bevelled cutting edge below, as shown in Fig. 138, is sunk a little way into the ground and carefully levelled. The brickwork is built upon it by a bricklayer working at ground level; when he has got the work up 3 or 4 feet another man excavates the ground within the kerb to a depth of about 1 foot and then gradually works the soil away from under the cutting edge evenly all the way round, so that the kerb may sink under the weight of the wall above. Another foot of soil is then excavated and the lowering repeated, whilst the bricklayer continues to build up the wall. Very great care must be taken to keep the kerb quite level as, if the steining gets out of the vertical, it may become impossible to sink it further.

Whichever method of construction is used, the thickness of the walling will usually be 9 inches, though occasionally it is more. The upper part, which is solidly built in cement mortar, is usually built of radiated bricks, but this is quite unnecessary for the lower part, which has open joints. The internal diameter of the well will generally be about 4 feet.

If iron cylinders are used as steining they are made up of sections, with machined flanges on the inside. Before these are bolted together their faces are smeared with a mixture of iron filings and sal ammoniac. This form of steining could usually be sunk into position on a kerb. The lowest section would of course have perforations.

Wells of small diameter are sometimes lined with concrete tubes, the lowest one or two being perforated. Reinforced concrete is also sometimes used, the thickness being about 4 inches with vertical and horizontal steel rods in the centre of it; the horizontal rods are bent to the form of hoops and are wired to the vertical rods wherever they cross.

Deep Wells. Wells which are sunk to considerable depths are dug out to only a depth of about 4 or 5 feet. From that depth they are completed by boring (also called "drilling") with special tools, the diameter being usually much less than that which is usual with a well, although bores of quite large diameter are possible. The borehole is almost always lined with steel tubing, which serves the purposes of holding the subsoil in position and of excluding surface water. The lining usually need not extend to the bottom of the borehole.

The methods of drilling may be classified into two distinct systems, the Percussion System and the Rotary System.

In the Percussion System the breaking up of the rock or soil is done by a chisel bit, which is screwed to a vertical rod, suspended from a derrick set up over the site of the borehole. As the work proceeds the rod must be extended by screwing on additional lengths of rod. The rods and tool are raised by a winch and allowed to drop under their own weight, so that the chisel digs into the stratum. When 3 or 4 feet of soil has been penetrated the tool is brought to the surface and replaced by a shell-bucket, which is a contrivance for hauling out the debris after this has been softened by water. The chisel is afterwards substituted once more and drilling continued. The objection to this method is the time which is lost in raising the tools and changing them and in using the shell-bucket. To avoid this it is sometimes the practice to use hollow rods and a hollow chisel with oblique holes at its sides and to force water down inside these by a pump at the surface. The water carries up (outside the rods) to the surface the cuttings or debris, which are settled in a settling tank and the water decanted off for use again. If this "hydraulic flushing" is used the drilling chisel has to be brought to the surface only when lining tubes have to be inserted.

In the Rotary System tubular boring rods, screwed together in 6-foot lengths, are suspended from a derrick and rotated by bevelled gearing at the surface. At the bottom the circumference of the rod has either saw-like teeth, fixed diamonds, or a serrated face resting on chilled steel shot. By these means a circular groove is cut in the bottom of the borehole and the inside core

works up into the tubular boring rod and can be brought to the surface for an examination of the nature of the strata. To facilitate drilling, water is circulated down the interior of the rods as a lubricant and in some cases enough water is pumped down to wash loose debris to the surface on the outside of the rods.

As already stated, in boring through the upper formations it is usually necessary to line the borehole with steel casing, whose thickness is generally from $\frac{3}{8}$ to $\frac{3}{4}$ inch, the tubes being 10 or 12 feet long with screwed ends, so that they can be fitted together to form watertight joints. The lowest length has at the bottom a steel shoe with cutting edge. Until some considerable depth is reached there will be no difficulty in lowering the lining into position, but after that it will need to be driven down with a ram or monkey. The lowering and driving is done in stages while drilling is suspended.

It is important to note that water will not always be obtained when a boring is made through an impermeable stratum to one which is permeable. Fig. 139 shows both a shallow and deep well, and so far as one can say from the data furnished by the sketch, water should be obtainable in both wells. The circumstances shown in Fig. 140, however, are quite different. The fault, or dislocation of the strata, ensures water being collected so that well A is ensured a supply, but with the permeable stratum dipping downwards, as it does, there will be no certainty of supply to well B, which would probably be a dry or dumb one. Deep wells are often termed artesian well, but the term does not correctly apply to all deep wells.

Artesian Wells. A true artesian well is one formed in a valley or "basin" under such conditions that the water rises up through it and discharges with some force. Thus, Fig. 142 shows the conditions favouring an artesian well. Assuming the water level, in the lowermost permeable stratum shown, to be at the line AB, water will rise approximately to that level through the well. The name artesian is derived from the fact that the first such well was sunk in the province of Artois, in France. One of the earliest artesian wells in London was that sunk in 1844 to supply the fountains in Trafalgar Square. It goes down 393 feet to reach the upper chalk formation. Since the date of its construction, however, the water level of London's underground water has steadily dropped, and the Trafalgar Square supply is no longer artesian. Actually a pumping chamber has been constructed well below the level of the Square and the fountains play by mechanical power.

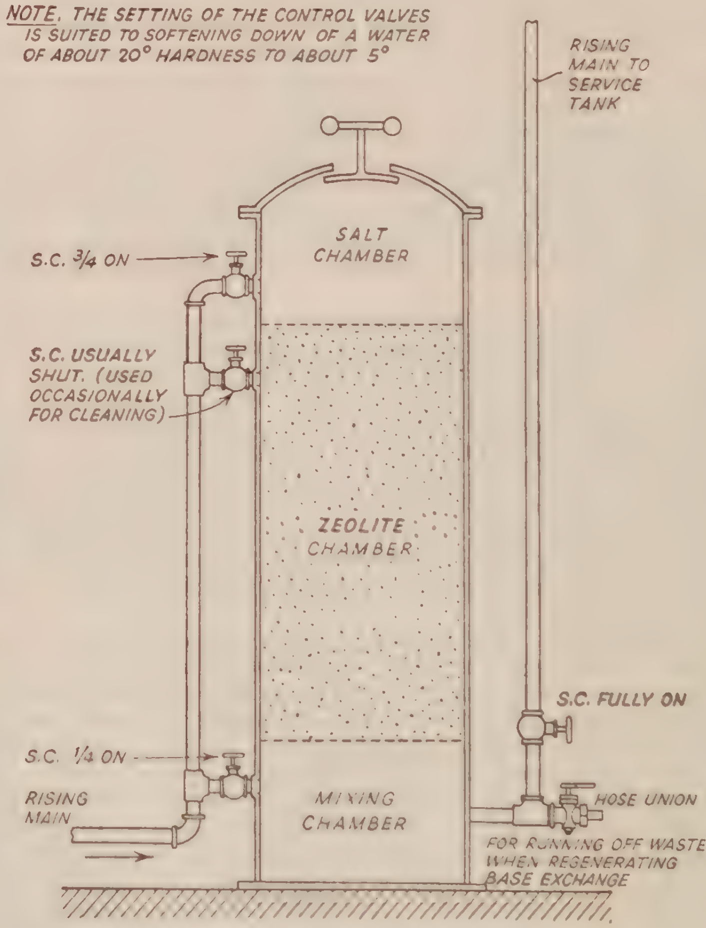
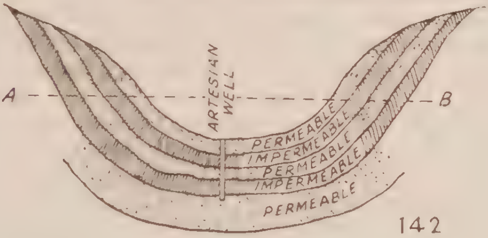


DIAGRAM OF TYPICAL SOFTENING PLANT (OR FILTER) SUITABLE FOR 6 OR 7 ROOMED HOUSE

141



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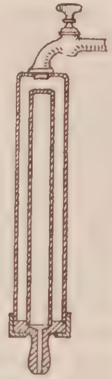

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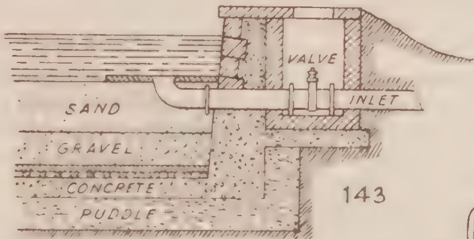

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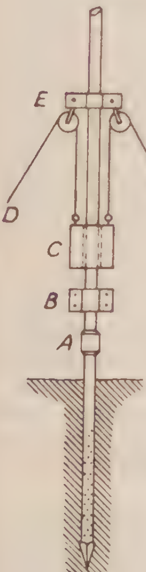

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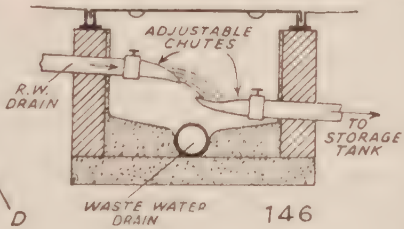

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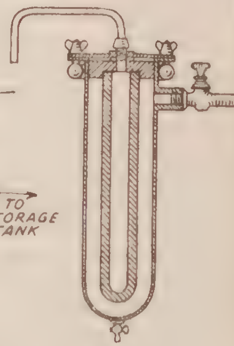

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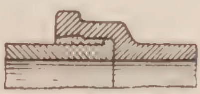

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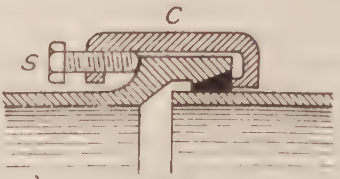


149

The water from artesian and deep wells is generally very even in temperature summer and winter. In a true artesian well the water rises to at least ground level and it sometimes happens that the natural lift is enough to carry it to the storage tanks without pumping.

Abyssinian Tube Wells. For a temporary supply, and for cottages in the country, "Abyssinian" tube wells are useful. They are made up of strong mild steel tubes, driven into the soil, one length being screwed on to another or, in fairly soft ground, the joint is made by means of collars. The bottom length has a hardened steel spike and is perforated for a length of about 2 feet to let the water in. Fig. 145 shows one method of driving. The lowermost length is shown in the ground and the next length is connected to it, A being the collar joint. At B two plates are firmly clamped to the upper length by means of bolts. At E is a similar clamp carrying two pulleys. Over these pulleys run ropes, marked D, attached to a heavy weight, or monkey, C. The monkey is pulled up by means of the cords and then allowed to fall, driving the tube in by its impact on the clamp B. An alternative way is to put a protecting cap over the upper end of the tube, with a separate rod above it carrying the monkey. In this case the impact comes on the cap, no clamp being used. This method is said to avoid damaging the tube, which sometimes occurs with the clamp method. When the water is reached a pump is screwed on to the uppermost length; for a short time the water is muddy, due to the clearing of the earth out of the perforations and the forming of a cavity around the bottom of the tube, but once this has been done the water runs clear. In any tube well, if the water level is not within 28 feet of the pump valve, the valve must be taken down the tube to within such distance of the estimated lowest level of the water.

Increasing the Yield of Wells. When pumping is carried on from a well, water is drawn in from every direction, so that, if another well is sunk within the area from which the first well draws its supply, the yield of the latter will be affected. The area drained by wells is an uncertain factor.

To increase the yield of a well, adits or tunnels are often driven horizontally at the bottom, a series of wells being sometimes connected in this way to concentrate the pumping arrangements in one well.

Upland Surface Water. We come next to the consideration of upland surface water and large inland lakes as a source of supply. The former is the water obtained by storing in reservoirs the water

which flows directly off the surface, and that which issues in springs, within uncultivated tracts of moorland. Such water is wholesome and soft, and many large towns have availed themselves of this source of supply, including Liverpool (from Vyrnwy in Wales), Bradford, Birmingham (from Wales), Leicester, Derby, Nottingham and Sheffield (from the Derwent Valley). Such waters are, next to rainwaters, the most free from dissolved inorganic matters, as they have not had time to dissolve solid matters from the soil. Examples of supply from lakes are Glasgow, which obtains its supply from Loch Katrine, about 35 miles away, and Manchester, which is supplied from lakes in Cumberland. The supply from lakes at a high altitude, safeguarded from pollution, is of a high order of purity.

In the case of upland surface supplies, the "gathering ground", or catchment area, is generally at a high altitude. Thus, in the Derwent Valley scheme, before referred to, the catchment area forms part of the hilly country known as The Peak district, and for the most part is moorland. It has an area of nearly 32,000 acres, all over 580 feet above sea-level; 26,800 acres are at a height of over 1000 feet and 11,600 acres are above 1500 feet.

The catchment area in such schemes is the area of land draining towards a stream or streams, and is bounded by the watershed line —a line on opposite sides of which the water flows in opposite directions. The quantity of water available from such a source is estimated in either of two ways: (1) by ascertaining the rainfall in the district, and calculating the quantity available after deducting a certain amount, approximately 12 to 15 inches per annum of depth, for loss by absorption and evaporation, the loss due to absorption depending, of course, on the nature of the geological formation; (2) by gauging the flow of the streams flowing from the valley for as long a period as possible, and, if a storage reservoir is to be formed, deducting a small amount of evaporation. The methods of gauging the flow are numerous, including weirs, floats, current meters, Pitot tubes, and other contrivances. From the weir the discharge can be calculated direct, but from the other methods the mean velocity is obtained, from which the discharge is found by the simple formula:

$$\text{Quantity} = \text{sectional area} \times \text{velocity, or } Q = AV.$$

The supply in all years is not the same and also is greater in winter than in summer; therefore large storage reservoirs are constructed to store up part of the winter supply, and the excess rainfall of wet years, in order to provide a supply in time of

drought. Such reservoirs take the form of artificial lakes, made by damming the outlet of the valley. The best site for a storage reservoir is a part of the valley where a comparatively short embankment will form a reservoir of large capacity.

Compensation Water. Where a reservoir is formed on a stream used by mill owners, farmers and manufacturers, a certain part of the supply must be set aside to compensate them. Usually about one-third to one-fourth of the whole available supply is set aside as compensation water, often stored in separate "compensation" reservoirs.

The available capacity or storage room in a reservoir is the volume contained between the highest and lowest working levels, and is less than the total capacity by the volume left for the collection of sediment. No hard-and-fast rule can be laid down for this, but it occupies in many good examples about one-sixth of the greatest depth of water at the deepest part of the reservoir. The storage reservoir is often adapted for use as a compensation reservoir also. The storage capacity of an impounding or storage reservoir is very considerable. The two reservoirs which were constructed as a first instalment under the Derwent Valley scheme have a total capacity of 3940 million gallons.

River Water. A large number of towns obtain their water supply from rivers, but many have had to abandon this source owing to increasing pollution by sewage and refuse from manufactories. London is the most notable example of a town taking its main supply from a river. As the dry weather flow of the river may be insufficient, storage reservoirs may be formed to impound the flood waters. This is done in the case of London, two impounding reservoirs having been already provided at Staines, having a total area of 421 acres, with a capacity of 3300 million gallons, while reservoirs have been constructed at Chingford in Essex, with a total area exceeding that of Hyde Park. Improved methods of purification and sterilisation have of late years made it possible to utilise rivers formerly regarded as unfit, so that there is no doubt that rivers will continue to afford a valuable source of supply for towns. With respect to supplies from rivers it is worth mentioning here the much-debated question of self-purification of rivers. It has been pointed out that water taken some miles below a source of pollution is purer than a sample taken nearer the source of pollution, and the opinion has been expressed that a river flowing with a mean velocity of about 4 miles per hour will purify itself within a distance of about 16 miles from the point of pollution. Some authorities say that when pathogenic or disease-bearing

bacteria pass into relatively pure water, they are in an unnatural medium and die off. On the other hand, some conclude that sedimentation is the chief cause of self-purification. If this be so, there is no guarantee that harmful microbes will not be present and be carried down by the next flood which stirs up the river bed.

River water is usually softer than that derived from wells and springs. It seldom happens that the supply can be delivered by gravitation, but it is usually cheaper to pump the water than to bring it from a great distance by gravitation.

Stored Rainwater. The last source with which it is necessary to deal is that furnished by the storage of rainwater. It is a source which rarely needs to be considered and then only in the case of an isolated country house. Generally, it is only used as a supplementary source, but at times it is the only one. Rainwater is very soft, therefore good for cooking and washing, but it is too soft to be very palatable, though somewhat improved by filtration. It is only out in the open country that this source is used and the question of the rain taking up impurities in its fall does not arise.

The collecting area is generally the roofs of the buildings. Slate should be chosen as the roof covering, it being less absorbent than tiles. If the water is to be used for drinking purposes, there should be no lead gutters or flats, owing to the possibility of solvent action of the soft water. The gutters and rainwater pipes should be of iron, protected against corrosion preferably by a process such as that introduced by Dr. Angus Smith and consisting of dipping the articles, when hot, into a hot solution of bituminous composition.

Surface Water Collecting Grounds. If the roofs do not furnish a sufficient collecting area, a special collecting area must be formed. It should be carefully fenced in to guard it from pollution and may be of either of the following forms: (1) a sloping surface of concrete finished with cement or asphalt, falling to a collecting channel communicating with the storage tank; or (2) a similar surface covered with special tiles to form a false floor supporting about a foot of earth covered with grass. The rainfall is partly filtered and purified by the earth and grass and passes through to the collecting floor below and thence into the channel. Any such surface should be isolated by a channel sunk around it and to a lower level.

Rainwater Separators. Where roofs are used as the collecting surface, gutters should be regularly cleansed and a rainwater separator can be used. This is a device for diverting the first part of the flow, charged with the washings of the roofs and gutters, to waste; it then automatically directs the after-flow to the storage

tank. An example is illustrated in Fig. 146, the working of which is clear from the sketch. In estimating the quantity that will be collected, allowance must be made for the quantity diverted to waste and for the loss by evaporation from the surface of the water in the underground storage tank. The proportion of rainfall available for actual supply is approximately as follows:

1. With roofs and similar collecting surfaces, a separator being used, about 65 per cent.

2. Ditto, but without a separator, about 85 per cent.

3. With a grass-collecting surface (part of the rain being retained by the soil), about 60 per cent.

Rainwater Storage Tanks. The storage tank should preferably be capable of containing from 90 to 120 days' requirements, according to the annual rainfall of the district, though much smaller tanks are often used. The shape of the tank on plan is not important but it must be watertight, not only to keep the water in, but to keep impurities out. From the foregoing a formula can easily be deduced to give the area requisite for the collecting surface, or the quantity obtainable from any given surface.

Suppose we are dealing with case (1) above, in which 65 per cent. is obtainable.

Let G = gallons required, or obtainable, per annum.
A = area of collecting surface in square feet.
R = rainfall in inches per annum.

There are approximately 6·25 gallons in a cubic foot.
Quantity in cubic feet = area in square feet × rainfall in feet.

$$\therefore \frac{G}{6{\cdot}25} = A \times \frac{R}{12} \times 65 \text{ per cent.}$$

$$\text{or} \quad G = \frac{A \times R \times 65 \times 6{\cdot}25}{12 \times 100},$$

from which, by simplifying,

$$G = 0{\cdot}34AR.$$

Transposing,

$$A = \frac{G}{0{\cdot}34R}.$$

For case (2) above, on the same reasoning we get—

$$G = 0{\cdot}44AR \text{ and } A = \frac{G}{0{\cdot}44R};$$

and for case (3),

$$G = 0{\cdot}31AR \text{ and } A = \frac{G}{0{\cdot}31R}.$$

Example. A household of seven people, requiring 15 gallons per head per day, is to be supplied only from rainwater collected from roofs and similar surfaces, a separator being used. The average rainfall is 28 inches per annum. Determine (1) the area of collecting surface necessary for the supply, and (2) the depth of a circular storage tank having an internal diameter of 16 feet, sufficient to hold 100 days' supply.

$G = 7 \times 15 \times 365 = 38{,}325$ gallons per annum.
$R = 28$ inches.

$$A = \frac{G}{0{\cdot}34R} = \frac{38{,}325}{0{\cdot}34 \times 28} = 4026 \text{ sq. feet.}$$

100 *days' supply*,

$$\text{Contents of tank in cu. ft.} = \frac{7 \times 15 \times 100}{6{\cdot}25} = 1680 \text{ cu. ft.}$$

$$\text{Depth of tank} = \frac{\text{cubic contents}}{\text{area}}$$

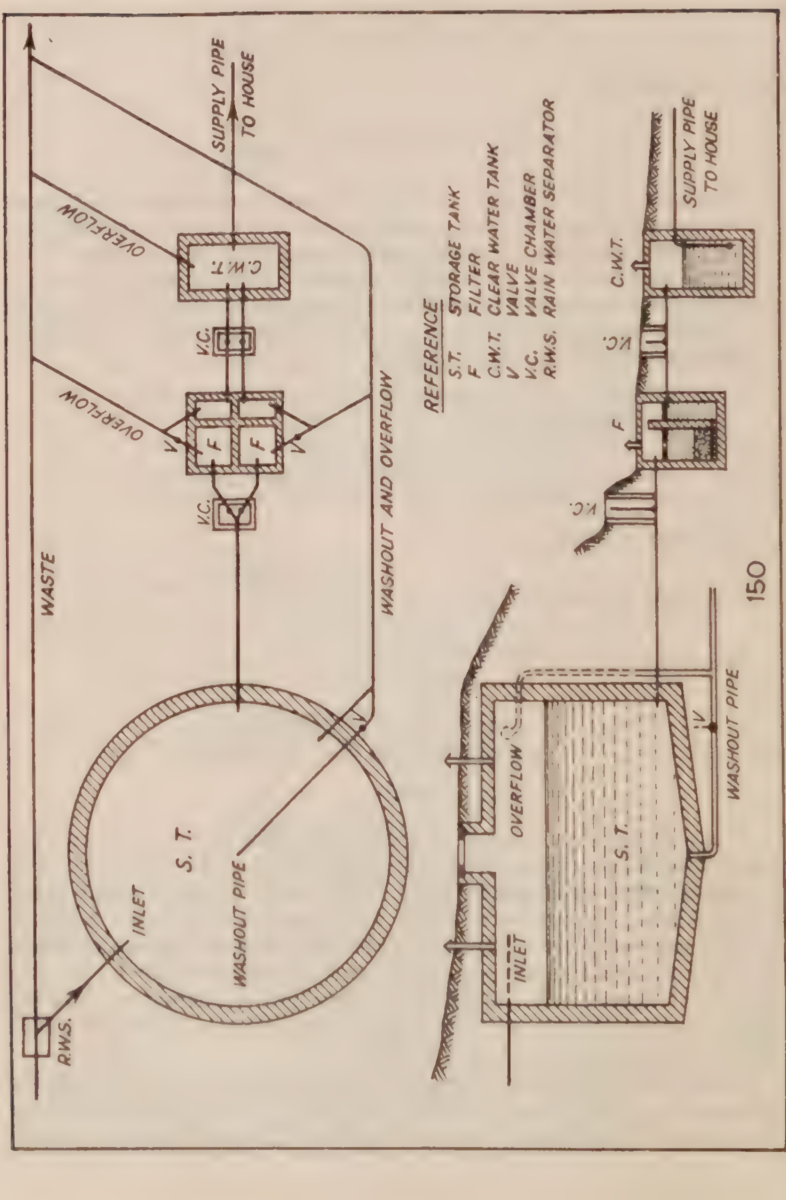
$$= \frac{1680}{0{\cdot}7854D^2} = \frac{1680}{0{\cdot}7854 \times 16 \times 16}$$

$$= 8 \text{ feet } 4 \text{ inches.}$$

The collecting area must therefore be 4026 square feet and the tank must have a depth of 8 feet 4 inches below the overflow pipe.

Construction of Storage Tanks. The tank could be constructed of brickwork or concrete, lined with cement mortar or asphalt, or of ferro-concrete. It could be roofed over with ferro-concrete in any case and must have a good-sized manhole cover to provide means of access. It should also have two or three ventilating pipes, carried up a foot or two above the ground and covered with conical shields to keep out impurities.

Small Filter Systems. As the water is to be used for drinking purposes, a filter should also be provided. The filters should be constructed of a bed of fine sand 1 foot 6 inches thick, supported


SUPPLY PIPE TO HOUSE
OVERFLOW
C.W.T.
V.C.
OVERFLOW
V
F
F
V
V.C.
WASHOUT AND OVERFLOW
WASTE
S. T.
INLET
WASHOUT PIPE
R.W.S.
V
REFERENCE
S.T. STORAGE TANK
F FILTER
C.W.T. CLEAR WATER TANK
V VALVE
V.C. VALVE CHAMBER
R.W.S. RAIN WATER SEPARATOR
SUPPLY PIPE TO HOUSE
C.W.T.
V.C.
F
V.C.
OVERFLOW
S. T.
INLET
WASHOUT PIPE
V

150

by a bed of washed gravel 1 foot thick. Such an arrangement will efficiently filter about 400 to 450 gallons per square yard per day; therefore one about 2 feet square, the smallest size that could be constructed conveniently, would be of ample size. To permit of cleansing, however, the filters should be in duplicate. Adjoining them should be a small filtered-water tank holding about three days' supply. The general arrangement of the parts of such a scheme might be as shown in Fig. 150 in plan and section. The sketch is diagrammatic, and to simplify the pipe lines, the R.W. drain *from* the house is shown travelling parallel with the filtered water on its way back to the house. Actually this will need adapting to the site and home plan. It will be seen that the rainwater pipes lead to a separator, marked R.W.S., from which one pipe enters the storage tank and another goes on to waste. From the storage tank a supply pipe is taken to a pair of filters, either of which can be thrown out of use by a valve, for the purpose of cleansing. Each filter therefore has its own outlet pipe to the clean or filtered-water tank, from which the main supply pipe to the house is taken. Storage tank, filters, and filtered-water tank should all be covered with manholes for access, and be well ventilated. All three should have overflow pipes, and the storage tank and filters should be provided with wash-out pipes at the bottom. The overflow pipe and wash-out pipes can be joined together outside the tank. When the valves are in pairs they can be placed in a small valve chamber, but a single valve can be made accessible by placing a vertical pipe over it. The calculated depth of the storage tank should be the difference between the levels of the overflow and outlet, the floor being sloped to the wash-out pipe. It will be seen that such a system is most conveniently arranged on a piece of ground with a good fall, but the various parts need not be so close together as is shown, for convenience, in the sketches.

Hardness in Water. It was stated early in this chapter that the so-called "hardness" of many waters is due to their containing certain inorganic matters in solution. Water is said to be hard if it makes a curdy precipitate when in contact with soap, instead of readily forming a lather, and its hardness is measured by its soap-destroying capacity. Hardness is chiefly due to the presence of bicarbonates and sulphates of lime and magnesia, but also, sometimes, to nitrates, nitrites and chlorides. It may take either a temporary or a permanent form, temporary hardness being due to bicarbonates and permanent chiefly to sulphates. Temporary hardness can be removed by boiling, which precipitates the carbonates, while the permanent cannot. Waters of the former type

lead to the furring up of boilers and hot-water pipes and are wasteful in laundry work. Both hard and soft waters have their uses, however. Thus, a very hard water is needed by the brewer for making pale ale, while for the darker beers a soft water is desirable. Soft water is also desirable for cooking purposes, a hard water making vegetables and meat, if cooked in it, harder and less palatable. Rainwater is about the softest obtainable; therefore, the rainfall being the original source of all water supply, the hardness, if any, in any particular water is due to impurities taken up by the water in its passage over or through the soil.

Generally speaking, surface waters are soft and subterranean waters hard, but it depends a great deal on the nature of the strata with which the water has come in contact; for example, from calcareous strata a hard water would result and from igneous a soft one.

Measurement of Hardness. Hardness is measured in degrees, and a sample is said to have 1° of hardness (on Clark's Scale) when its soap-destroying power is equal to the effect of 1 grain of carbonate of lime in a gallon of water. Each degree of hardness in 1 gallon of water wastes from 8 to 9 grains of soap. A water having not more than 5° of hardness is classed as a soft water and one containing anything above 15° as a hard water.

Softening Hard Water. In order to understand the various methods of softening hard waters it is necessary to know that there are two "carbonates" of lime and magnesium. One is the true carbonate, of which hard limestones are a fairly pure example and chalk is a more impure form; this carbonate is practically insoluble in pure water. The other is the bicarbonate, which can be regarded as a combination of the carbonate with carbon dioxide; the bicarbonate is soluble in water.

Boiling a water which contains bicarbonate in solution results in the carbon dioxide becoming separated and driven off into the air with the steam. Carbonate remains and this, being insoluble, is precipitated and forms a "fur" on the containing vessel. This fur is very harmful in boilers and hot-water pipes, since it is a bad conductor of heat, and this is one of the chief reasons for adopting some method of the reduction of hardness in a town supply, or in that part of it which is used for steam-raising.

Strange though it may seem at first, a very usual method of reducing temporary hardness in water on a large scale is to add lime, or rather a solution of lime in water.

When a solution of lime is added to water containing a bicarbonate it separates the carbon dioxide from the bicarbonate, so that

the latter is reduced to the form of carbonate, which is insoluble; the liberated carbon dioxide itself combines with the lime, also forming insoluble carbonate. The insoluble carbonate must be given plenty of time to settle in tanks, from which it can be periodically removed, or else it will be deposited in the water mains.

Soda Ash Process. An effective treatment of a water which is "permanently" hard, i.e. which contains sulphates, is by means of sodium carbonate (also known as "soda ash"). The result is that the calcium (or magnesium) sulphate and sodium carbonate become changed to calcium (or magnesium) carbonate and sodium sulphate. The carbonate thus formed, being insoluble, is precipitated and removed; the sodium sulphate remains in solution, but is not objectionable if present in only reasonable quantities.

The soda ash method of treatment for softening water is the same, whether it is desired to remove temporary and permanent hardness, or temporary hardness only. The hard water which is to be treated enters over the top of a high tank and in doing so is made to turn a water-wheel, which drives the paddle-wheels to which reference will be made below. The chemicals (i.e. lime, with or without soda ash) are added, the amount being proportioned to the amount of hard water flow-in, numerous automatic devices being available to secure this result. The mixture is agitated by means of paddle-wheels and passed into a settling tank, where most of the carbonate is deposited. For its final clarification it is passed through a filter; this may be of wood fibre, placed between perforated plates, but nowadays rapid sand filters are more often used, especially in large installations. By the means described above the hardness of a water can be reduced to about 2°, which is a very soft water.

Base Exchange Process. The above method of softening is generally regarded as the best for use on a large scale, as on a town's supply. For use on a small scale it has disadvantages, notably the necessity of disposing periodically of the carbonate sludge. For domestic use the "Base Exchange" (or "Zeolite") method is more often adopted. It removes both temporary and permanent hardness, and can be adapted to both domestic and town supplies. In this process the water is passed intermittently through a bed of natural or synthetic Zeolite or sodium silicate. The bicarbonates and sulphates of lime and magnesium become bicarbonates and sulphates of sodium, which remain in solution but are not objectionable; the silicate of sodium becomes silicates of lime and of magnesium and this, being insoluble, remains in the

filter. When a considerable part of the silicate has been changed in this manner the water is shut off from the bed and a solution of sodium chloride (common salt) is passed slowly through it; a chemical reaction takes place by which the silicate returns to its original form of sodium silicate, whilst chlorides of lime and magnesium pass off in solution to waste. The bed of silicate is then ready for action once more. A diagram of such a filter suited to an average suburban house is given in Fig. 141.

The base-exchange method is not suitable for a water containing iron, which causes deterioration of the silicate, and it is not suitable for a water containing suspended solids, unless these are first removed by filtration.

It is seldom that natural waters are perfectly neutral in character, being nearly always either slightly acid or slightly alkaline. The student of chemistry, who has been taught to distinguish between acids and alkalis by the action of a sample on litmus paper or litmus solution, would not find this method of much use in examining natural waters. There are, however, a number of other "indicators" of a character similar to litmus, but more sensitive, by means of which a very accurate observation as to the condition of a water may be made. One may purchase a very useful "Universal" indicator solution with which, by adding a drop or two to a sample of the water, a distinct colour reaction is observed, indicating the approximate degree of acidity or alkalinity of the sample, within a fairly wide range on either side of the neutral; but, for a greater degree of accuracy, for use in the control of chemical treatment of the supply, other indicators are used and the resultant colours are compared with those of standard colour solutions, the most useful of these indicators being brom-thymol-blue, cresol-red and methyl-red. The result of such tests is expressed by its hydrogen-ion concentration, also known as its *p*H value. To explain the meaning of this would involve an explanation of some of the principles of electro-chemistry, and it will be sufficient to say that neutral water has a *p*H value of 7, that water with a *p*H value greater than 7 is alkaline and that water with a value less than 7 is acid. The importance of this matter lies in the fact that acid water is liable to attack lead pipes and cisterns lined with lead, with the result that lead poisoning may result to consumers. Hard waters are generally alkaline, so that with them there is seldom any danger of "plumbo-solvency", as it is termed, although it is known that water which is hard because of sulphates, but contains little or no carbonate, may also be plumbo-solvent if it contains nitrates also.

Soft and Acid Waters. The soft waters which come from moorlands are often acid and, when they are, there is a real danger of lead poisoning unless steps are taken to neutralise the acid. It is often erroneously stated that soft waters are plumbo-solvent; this is not necessarily the case, for a soft water may be quite neutral, i.e. neither acid nor alkaline; it is only when it is acid that danger arises.

In copper tubes non-acid water forms an oxidised film which prevents any harmful action. With acid water this protective coating is not formed, but the green tinge acquired by the water will be a visible warning with a copper concentration less than that which will be harmful to health.

If a water is acid the usual remedy is to treat it with lime or carbonate of lime. The acids present are usually the result of bacterial action upon vegetation (including algae), and the chief one is carbon dioxide (also known as carbonic acid). This will combine with the lime, or the carbonate of lime, to form bicarbonate of lime, which remains in solution and, if sufficient be added, the water is now feebly alkaline and a little harder than it was, though it would still be classed as a soft water.

It may seem peculiar that lime should be used for two almost opposite purposes: to soften a hard water, which incidentally reduces its alkalinity, and to neutralise the acidity of an acid water, which incidentally hardens it. Any difficulty in understanding this will however disappear when it is realised that the only reason why it softens, and reduces the alkalinity of, a hard water is that carbonate is precipitated and then physically removed; if it were not removed the hardness and alkalinity would be even greater than before.

Iron Salts in Solution. It sometimes happens that water is discoloured by the presence of iron in solution. Much of this can be precipitated if the water is well aerated; this can be effected by exposing it to the air in open channels or, better still, by allowing it to fall in cascades down a series of steps, discharging it as a fountain into an open reservoir, or by any similar means. In extreme cases more drastic treatment may be required, such as by lime and compressed air.

Polluted waters are sometimes the only ones available for drinking, but even these can be made safe for use; so that we now have to consider the methods of purifying water which contains organic matter in suspension and solution and which is charged with large quantities of bacteria. The principal methods are by sedimentation, filtration and sterilisation.

Sedimentation is useful only for the removal of suspended matters and some of the bacteria; it is not a sufficient treatment of water polluted by sewage, but is a useful first step in its purification. If water is kept in a quiet state for a sufficient time the heavier suspended matters will settle, carrying with them some of the bacteria, and the clarified upper part of the water can be decanted off; the deposited sludge must be periodically removed. The settling process is often aided by the use of sulphate of alumina; this, in combination with a bicarbonate present in the water, will cause a cloudy precipitate to form and fall to the bottom, dragging suspended particles and bacteria with it. If there is practically no bicarbonate present in the water, lime or carbonate of lime must be added with the alumina.

Sand Filtration. Filtration on a large scale is performed by passing the water through sand, contained either in open beds or in closed tanks. The open "slow and filter" is contained by walls and floor, usually formed of reinforced concrete.

The action of such a filter is partly mechanical and partly biological. The former action holds back the suspended matters and forms a film on the upper layer of sand; this film is charged with bacterial life, brings about the nitrification of organic matter, and arrests the passage of bacteria. The efficiency is due entirely to this film on the surface and until the film is formed bacterial life is not removed. After a time, however, it becomes so dense that, although the efficiency is increased, the passage of water through it, at a reasonable rate, becomes difficult. A thin layer of the sand is therefore scraped off and the process begun again, the water being run to waste for about five days till the film has begun to form again. This necessitates there being at least two filters, but there are generally more.

The bed of sand should be at least 2 feet thick at first; this gradually becomes reduced by the scraping, but should never be allowed to get less than 1 foot in thickness. It should then be again restored to its original depth by the addition of more sand. The sand rests on two or three layers of gravel, graded in sizes, the largest at the bottom, the combined thickness of these layers being about 15 inches. On the floor a network of drains is formed to receive the filtered water and conduct it away. They can be of open-jointed pipes, or of special tiles of many shapes, or be formed with bricks. Correctly designed under-drainage is a most important factor. From these under-drains the water flows through a control valve and rises in an outlet well, from which it passes over a weir to a pure water tank or channel. The water should not flow

down through a filter bed at a greater velocity than about 4 inches per hour, at which rate the filter will deal with 2 gallons per square foot per hour. This rate is secured by means of the control valve, referred to above, adjustment of which will alter the level of water in the outlet well and therefore will alter the "head" on the filter. When the head necessary to attain the desired rate of flow has increased, through silting up of the sand, to 2 feet 8 inches, it is time the sand is scraped. The depth of water over the top of the sand must not be less than 2 feet or the water will become unduly warmed in hot weather.

Slow sand filtration, efficiently carried out, will remove all suspended matters, oxidise practically all the organic impurities and remove as large a proportion as 96 to 99 per cent. of the bacteria. Fig. 143 shows a section through the inlet end of an ordinary form of sand filter, the inlet taking the shape of a bell-mouthed bend, surrounded by a stone slab to prevent the disturbance of the sand around it. Below the gravel a drain grate of bricks is shown, the floor falling to a sunk main drain in the middle. Such a drain would lead to a small chamber at one end, containing means of regulating the depths of water on the filter, according to the condition of the film on the surface of the filter, before referred to. This can be done by means of a sluice valve. Leading up the walls, around the filter, from the drainage grate at the bottom to a height of about a foot above the ground, would be a series of ventilating pipes. The foregoing gives a brief description of the ordinary type of filter, but it will, of course, be understood that there are many modifications, particularly as regards the arrangement of the regulated outlet.

The slow sand filter is not, by itself, suitable for treating a water which is, ordinarily or occasionally, heavily charged with suspended matter, as is the case with many rivers and streams, because of the expense and inconvenience of the frequent scraping and sand-washing that would be required. In such cases there should be either a preliminary settlement tank, or a series of "roughing" filters. The latter consist of perhaps three or four filters, of gravel, the size of which decreases in each succeeding filter; these arrest most of the suspended matter and can be cleaned periodically by flushing them through in a backwards direction with a mixture of water and compressed air.

Rapid Gravity Filters. Alternatives to the "slow sand filter" are the "rapid gravity filter", with which chemical precipitation and sedimentation are generally necessary, and the "rapid pressure filter", which works better without pre-sedimentation. Either of

these occupies far less space than "slow sand filters" and the pressure type can be installed on a pipe line without appreciable loss of head. Whereas the rate of flow through the older type of filter must not exceed 4 inches per hour, or 2 gallons per square foot of surface per hour, in the "rapid" type the rate may be from 10 feet up to 16½ feet per hour, or 60 to 100 gallons per square foot per hour, according to the condition of the water to be treated.

Prior to passing into the filter chemical treatment is necessary. The nature of this will depend entirely upon the degree of temporary hardness (or bicarbonates) present in the raw water. If entirely absent, chalk, hydrated lime or soda ash must be added, but prior thereto sulphate of alumina in solution is introduced and this, combining with the carbonates, forms a cloudy precipitate or "floc". The success or otherwise of the process depends largely upon the nature and quantity of this "floc". In most instances far too much "floc" results, but this is all to the good of the process and the excess must be allowed to precipitate in a suitably designed sedimentation tank, where the water will travel slowly through the tank in the space of two to four hours according to circumstances. Thence it should pass to the filter, carrying sufficient "floc" quickly to fill up the spaces between the sand grains with this jelly-like material. It has been stated above that in the "slow" process all mineral and vegetable solids in suspension, as well as bacteria, are caught in the surface film of the filter. This is not the case in the rapid type, where the whole thickness of the filter is necessary for the interception of bacteria, owing to the high velocity of the flow. As a consequence of the increased work put upon the comparatively small area of filter, very frequent cleaning becomes necessary; generally speaking this will be once in every twenty-four hours, and the necessity for it is ascertained from gauges showing the rate of filtration, which will drop as use of the filter proceeds, or by the difference of head on the filter at the inlet and outlet. When this amounts to 6 to 6½ feet in gravity beds, or 10 feet in the enclosed pressure type, it is time to wash.

The cleansing of a rapid filter is done by reversal of the direction of flow of filtered water, accompanied by an agitation of the clogged filter with suitable rakes or compressed air.

Pressure Filters. It may be here noted that the "pressure" filter (often termed a "mechanical filter") consists of a cylindrical steel tank, at the bottom of which is a false perforated floor supporting the 3 or 4 feet of filtering sand. In this floor are a large number of nozzles which serve the double purpose of collecting the

filtered water, when the flow of water is downwards in the filtering process, and of distributing equally the wash water in the process of reversal of flow. If compressed air is used to disturb the sand the same nozzles are available. In some types of filters the compressed air is used at the same time as the water, in others the operations succeed each other. It is important that it should be so arranged that the sand is not washed out of the filter by an excessive flow of water or air. The flow of the wash water must also be controlled for the same reason if disturbance is done by means of rotating rakes.

It is a matter for careful bacteriological investigation, but normally the filter must be run to waste for fifteen minutes on restarting after cleansing.

If the above description of the process be carefully considered it will be realised how the nature of the "floc" will affect the rate of efficient filtration, the frequency of washing, and the length of the period of running the early filtrate to waste.

The "rapid" filter is quite as efficient as the "slow sand" process, but is far more liable to failure and it requires very constant supervision and investigation. With a raw water containing any large number of pathogenic organisms, it should not be relied upon except with the subsequent use of a sterilising agent such as chlorine, which may be made an absolute safeguard to any supply, and which, by the introduction of new methods of application, is being brought into use in nearly all large municipal works.

At the Thames-side works of the Metropolitan Water Board, rapid gravity filters are being used without coagulants, merely as preparatory or roughing filters, and the result is that the water can afterwards be passed through slow sand filters at a greatly increased speed, with comparative safety; but even this double process of filtration is not permissible for Thames water without subsequent chlorination. It is particularly useful during those seasons when the raw water is heavily infested with "algae" (minute vegetable growths), under which condition the slow sand beds soon become quite unusable without the preliminary roughing filters.

Domestic Water Filters. Domestic filters are of two kinds, (1) the low-pressure, the most usual form of which is the upright jar with a tap at the bottom, and (2) the high-pressure, which is attached to a tap on the pipes supplying the house.

The low-pressure portable jar filters are of two types: (*a*) those containing a quantity or block of filtering material such as animal or vegetable charcoal, manganous carbon, spongy iron, etc.; and

(*b*) those containing hollow, candle-shaped units of baked clay. The former are to be avoided, as bacterial researches have shown that filters of this type are not really germ proof, while a good candle filter is.

Candle Filters. The high-pressure candle filter is of various forms, but the principle in all is the same. A metal case contains a hollow candle-shaped filter of fine unglazed earthenware. The water filters through from the outside to the inside of the candle, depositing a scum on the outside of it, which is readily removed by taking the candle out of the case and cleaning it. Fig. 144 shows a section through the Pasteur-Chamberland form. A metal case contains the "candle" and is screwed on to the tap. At the bottom is a glazed nozzle outlet. By unscrewing the collar just above this, the candle is at once freed for cleansing purposes. Fig. 148 shows the Berkefeld filter, which is of rather different construction. It has a thicker candle formed of baked fossil earth and filters more rapidly, but its efficiency is less. The water in this case is drawn from the top of the filter through the small pipe shown. The candle is removed by unscrewing the two wing nuts at the top. The small tap at the bottom is for the purpose of scouring out. The Berkefeld filter should be cleansed daily. Another type of this filter is the Doulton. These filters all pass the water very slowly and are therefore often provided of larger size and in cases or batteries containing two or more candles. In the same way, several candles can be put into a filter of the jar form for low-pressure filtration, and this is the only type of jar filter recommended.

It is hardly necessary to point out that domestic filters of these types, needing, as they do, frequent cleansing, are mere makeshifts and not to be compared in efficiency with the scientifically managed purification works of a water authority. They may, however, be the only appliances available to small country houses.

It has already been pointed out that the number of bacteria present in a raw water is considerably reduced by sedimentation, and further reduced to quite a minute quantity by efficient filtration. With most water supplies this will be sufficient for safety. Where, however, the raw water was a highly polluted one, even the removal of 99 per cent. of the bacteria will not make the water quite safe, especially as the bacteria which are still present will multiply rapidly in a short period. To make such waters safe the bacteria must be exterminated and this can only be done by sterilisation by means of certain chemicals.

The science of sterilisation of water has made such progress in

recent years that it has enabled some water authorities to take into use once more old sources of supply which had been discarded owing to their polluted state. Many authorities, too, have been enabled to bring into use local rivers and so avoid the expense of bringing water from great distances.

Ozone has been tried as a sterilising agent, but the process has hitherto been too expensive for general use. It is becoming less expensive and it is quite possible that before many years are past the method will be in general use. The use of "ultra-violet" rays has been advocated, but it seems that this method also is expensive: in any case it cannot be said to have been sufficiently tested on a large scale. The two principal methods in use to-day are "chlorination" and the "excess lime" treatment; of these the former is in more general use.

Chlorination. Chlorine may be obtained for adding to the water in any of the following forms: Firstly, as a solid, in the form of calcium hypochlorite (commonly known as "bleaching powder"), this being dissolved in a small body of water before being added to the main supply; this method was used for the supply of armies during the war of 1914–18 and for some years by the Metropolitan Water Board, but the plant required for dissolving the powder is bulky and the method may be regarded as obsolete. Secondly, as a liquid, named "Chloros", in which form it may be convenient for small installations or in emergencies. Thirdly, as a gas delivered under pressure in steel cylinders, this being the method in almost universal use to-day.

The chief difficulties met with in any chlorination process are that chlorine in the presence of moisture, or any strong solution of chlorine, corrodes metals and that the amount to be added to the water has to be adjusted with precision; if too much is added the taste will be unpleasant; if insufficient, sterilisation will not be complete, and the margin between these two extremes is narrow. To meet these difficulties it is essential to install a properly designed apparatus, called a "chlorinator", which is a small and compact contrivance.

Chlorine in a free state, if added to a water still containing organic impurities, will first of all oxidise these, and chlorine so used will not be available for destroying bacteria. It is therefore necessary to add a little more than is required for such oxidation. Chlorination consequently almost invariably is done after filtration and not before it, so that the amount added shall be as small as possible. The only circumstances in which it may be desirable to chlorinate before filtration is where it is necessary to destroy

algae (minute vegetable growths), which would block the filters in a very short time.

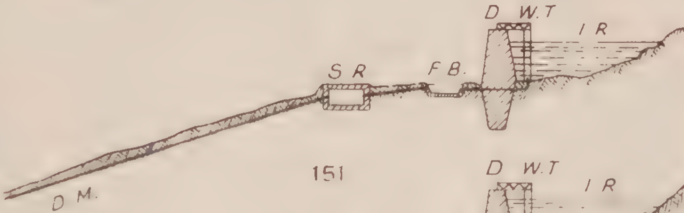
The explanation of the effectiveness of the process is that chlorine combines with hydrogen and releases oxygen; "nascent oxygen", i.e. oxygen newly formed by a chemical process, is a far more active agent than ordinary oxygen. The dose usually required for a filtered water is about $\frac{1}{4}$ to $\frac{1}{2}$ part per million parts of water.

It is found with some waters that an effective dose of chlorine must be so large that the resulting taste of the water will be most objectionable, especially when the water is boiled. Fortunately, objectionable taste can be prevented by ensuring that the water contains an excess of free ammonia, which may be done by the addition of a solution of ammonium sulphate, prior to the introduction of the chlorine. The substance thus formed, known as "chloramine", is a germicide equally as effective as free chlorine, and it has the advantage of not being used up in the oxidation of organic matter. It should be noted that there is delayed action in the process and water so treated should not be allowed to reach the consumers until four hours have elapsed.

Excess Lime Method. The "excess lime" method is usually rather more expensive than chlorination. It has already been explained that lime is sometimes used to soften waters containing bicarbonates, and also to neutralise the acidity of waters containing acids. If more lime is added than is required for either of these chemical reactions, it will be available for the destruction of bacteria. After sufficient time has been given for sterilisation, the excess lime is precipitated by blowing carbon dioxide through the water in a "carbonating chamber". The resulting carbonate of lime is removed, dried and heated, to drive off the carbon dioxide, so that the lime is recovered for re-use.

Removal of Colour. Finely powdered "activated carbon" is now being largely used for the elimination of colour and taste from water that cannot otherwise be freed of them. This is the only method of getting rid of the very offensive taste which results from the decomposition of algae. It is not a costly process, but the carbon must afterwards be removed by filtration and this adds to the complication of the treatment works. It is now most effectively used at the Southend Water Works, where objectionable taste would otherwise result from the excess lime process in a river water.

Impounding and Service Reservoirs. There are many ways in which the water supply works for a town can be arranged, depending on the levels of the land between the source of supply and the



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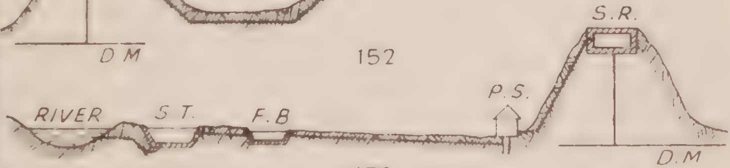

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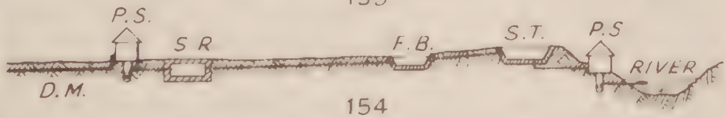

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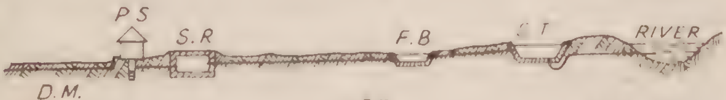

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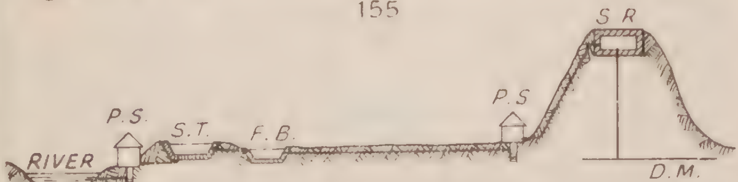

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point of distribution, and involving either gravitation or pumping systems. A few examples will show some of the many cases that occur in practice and give an idea of the relative positions of the units forming such a scheme. Thus Figs. 151 and 152 show diagrammatic sections through gravitation schemes, and Figs. 153 to 156 similar sections through pumping schemes. Thus in Fig. 151 the waters passing through a valley are held up by a dam, D., in an impounding reservoir, I.R., the outlet of which is controlled by a valve at the foot of a valve tower, V.T. It passes on to filter beds, F.B., and then into a service reservoir, S.R., from which the distributing mains, D.M., pass to supply the town. A somewhat similar arrangement is shown in Fig. 152, but the levels permit of an elevated position for the service reservoir nearer to the town, which is a better arrangement.

In Fig. 153 the supply is drawn from a river, and passes first into a settling or sedimentation reservoir, then on to filter beds, after which it goes to a pumping station, P.S. From there it is pumped up to an elevated service reservoir, the height of which gives the necessary pressure in the distributing mains; a pressure great enough to ensure the water being thrown over the tops of the houses in case of fire. In Fig. 154 the levels are such that the water has to be pumped up into the settling reservoir, from which it flows by gravitation to the filter beds and on to the service reservoir, the pressure in the distributing mains being provided by a second pumping station. Fig. 155 is a similar case, but the levels permit of the water reaching the settling reservoir by gravitation. Fig. 156 shows a somewhat similar case to Fig. 155, but the filters discharge into a main, leading to pumps which raise the water to an elevated service reservoir, from which the distributing main descends.

If the supply is from a well or borehole the general principles of the arrangements of Figs. 154 or 155 could be used, but no sedimentation reservoir would be needed.

If a high site is available near the town the water could be pumped direct from the well to the service reservoir, passing through pressure filters en route; thence to town by gravity. If no such site is available the water will still be pumped to the service reservoir through pressure filters and will have to be pumped again from there into the town mains.

Different Types of Reservoir. We may next briefly consider these various forms of reservoir, their construction and capacity. The reservoirs necessary for the supply of towns with water include: (1) impounding or storage reservoirs; (2) compensation

reservoirs, which are often rendered unnecessary by the special form of the impounding reservoir; (3) settling tanks, or sedimentation or depositing reservoirs; (4) service reservoirs.

Impounding Reservoirs. Impounding reservoirs are generally partly natural and partly artificial. The site must be such that a dam of comparatively short length will form a reservoir of large capacity. There must be an impervious bed under the whole site at a reasonable depth to ensure water tightness, and any cracks or fissures near the site of the dam must be filled by pumping cement grout under pressure into boreholes. The slope of the bed must be fairly uniform: there should be few parts of shallow depth, as this encourages vegetation. The dam may be entirely of masonry, of concrete or reinforced concrete, or a mixture of concrete and masonry, in which the body of the dam is formed of very large rough blocks of stone embedded in concrete and the whole faced with prepared blocks of stone or pre-cast concrete blocks; or lastly, it may be an earthwork dam faced with stone setts and with a thick wall of clay puddle in the middle, the earth being sloped at about 3 to 1 on the side which will be submerged and about $2\frac{1}{2}$ to 1 on the other side. In any case the foundation of the dam must be carried well down into the impervious stratum. Thus, the Howden dam, in the Derwent Valley scheme, is 1080 feet long and of masonry, has a height of 117 feet, and is carried down below the ground to a depth of 125 feet, the bottom 55 feet taking the form of a watertight curtain wall about 6 feet thick. The greatest thickness of the dam is 176 feet and its entire weight is about half a million tons. It was afterwards found that the hill-sides up the reservoir were not absolutely watertight, and "wing" walls were constructed up each side of the valley for a distance of 3000 feet. In similar works executed to-day an attempt would be made to secure watertightness by pumping cement grout into boreholes in the fissured rock, a method of procedure which is far cheaper than that of constructing long wing walls. In all such schemes provision must be made for overflow of flood waters; if the dam is of earth and puddle the overflow must be on solid ground around one end of the dam, but if it is of concrete or masonry the water may be allowed to overflow the dam itself. Occasionally a flood-water channel is constructed, so that turbid water after heavy rain may by-pass the reservoir instead of flowing through it. All timber should be removed and all vegetation should be burnt before the reservoir is fit for use, and there should be no houses left on the catchment area above the water level.

Capacity of Impounding Reservoirs. The capacity required for

impounding reservoirs is usually determined by Hawksley's formula, which is:

$$D = \frac{1000}{\sqrt{F}},$$

in which D = number of days' supply to be stored, and

$F = \frac{5}{6}$ average annual rainfall in inches.

A normal capacity would be about 180 days' supply.

Compensation reservoirs may be of the form just described, or entirely artificial, having walls and floor of concrete, backed by clay puddle. Their capacity should be about one-fourth to one-third of that of the storage reservoirs.

Settling reservoirs are usually entirely artificial. The object of them is to provide for the settlement of the suspended matters at the least possible expense. In a perfect system four should be used, one filling, one settling, one discharging on to the filters, and one held in reserve. They are usually cleaned out about twice a year. Humber's rule for the area of settling tanks is:

$$\text{Area in square feet} = \frac{\text{Demand in cubic feet per day}}{\text{Velocity of deposit in feet per day}}.$$

The area is quite independent of the depth, which is usually from 10 to 15 feet, a less depth encouraging the growth of vegetation. Settling tanks are not always worked on the intermittent principle described above and are sometimes continuous in action, the water always flowing through them at a slow rate. In the latter case they should be long and narrow in order to ensure a uniform flow as opposed to a current through the middle.

Service Reservoirs. Service reservoirs are of many forms. They may be open or covered; formed entirely below ground, entirely above, or partly one and partly the other, the upper part being embanked. The daily demand for water varies, and the object of these reservoirs is to keep a reserve near at hand on a compensating basis. A frequent capacity is half a day's supply if the source of the supply is quite near, but if the water is to be brought from a distance, the capacity is greater, to act as a store, in case of accidents to the mains conveying the supply through such a distance. It should be noted, however, that water which has been treated and improved in quality may deteriorate rapidly in service reservoirs, so that storage should not exceed two or three days. They can be of concrete, or reinforced concrete, which is now largely used for them, or even large iron or steel tanks

supported on a tower of stone, brick or iron, in order to get sufficient height to give the required pressure in the mains. They should be placed as near the point of delivery as possible. Probably the largest service reservoirs in the world are those of the Metropolitan Water Board at Honor Oak, having a capacity of about 60 million gallons.

Water Pressure or Head. A few notes will not be out of place here in reference to the pressure on the sides and floors of tanks and in pipes. Water pressures are generally given in lb. per square inch or in "head" (which represents the height of water surface above the point where the pressure is exerted).

One cubic foot of water weighs, approximately, 62·5 lb., so that the weight or pressure on a level surface 12 inches below the water surface would be 62·5 lb. for a square foot or $\frac{62 \cdot 5}{144} = 0 \cdot 434$ lb. per square inch. This pressure, owing to the laws of hydraulics, presses upwards and sideways as well as downwards, and is quite irrespective of the slant of the surface on which the pressure bears or of the total quantity of water concerned, so that the pressure on the eardrums of a bather 12 inches below the surface of the water in a small bath would be the same as if he were 12 inches below the surface in mid-Atlantic—if we ignore the fact that salt water is slightly heavier.

Water brought from a tank in a loft or cistern room, via a $\frac{1}{2}$-inch pipe to a ball-valve of a W.C. tank on the ground floor at (say) 20 feet lower level, will exert a pressure of "20 feet head" on the ball-valve washer, which is equivalent to $20 \times 0 \cdot 434$ lb. per square inch, i.e. 8·68 lb., quite irrespective of the size of the service tank or the quantity of water it contains.

Example. Determine the pressure per square inch on (*a*) the floor of a reservoir when the depth of water is 20 feet, and (*b*) the wall of the reservoir at a point 8 feet below the surface of the water.

The fact that the walls may be vertical or sloping makes no difference to the answer.

(*a*) Pressure per sq. in. on floor of reservoir

$$= 20 \times 0 \cdot 434$$
$$= 8 \cdot 68 \text{ lb. per sq. in.}$$

(*b*) Pressure on wall 8 feet below the surface

$$= 8 \times 0 \cdot 434$$
$$= 3 \cdot 472 \text{ lb. per sq. in.}$$

Again, take the case of a water main:

Example. A 24-inch water main communicates directly with a reservoir which discharges into it. The valve at the outlet of the main is shut, and the difference in level between the centre of the valve and the water surface in the reservoir is 190 feet. Find the pressure per square inch on the centre of the valve.

Pressure per sq. in.

$$= 190 \times 0{\cdot}434 = 82{\cdot}46 \text{ lb. per sq. in.}$$

If the valve were *open*, the pressure would not, of course, be the same, but if the pipe will stand the pressure when the valve is shut, it will certainly stand the less pressure when it is open. The case of pressure in liquids in motion is beyond the scope of this book.

Distribution. Having seen the various ways in which water can be collected and supply works arranged, let us next consider its conveyance from the source to the point of distribution. This may be arranged by means of (1) open channels, (2) covered channels and tunnels, (3) cast-iron or steel pipes, and (4) reinforced concrete pipes.

Open Channels. Open channels can only be used where the ground allows of suitable slope. It is obvious that such a channel cannot follow the undulations of the land and go up and down hills. It may be formed of concrete, bricks, or masonry. The objections to an open channel are that the water is deteriorated by exposure and wasted by evaporation, gets heated in summer and in winter expense is incurred in keeping the channel open during frost. The "New River", one of the conduits supplying London, is a well-known example of an open channel.

Covered Channels. Covered channels are of somewhat similar construction to those just described, but roofed over, and may be either circular in section, or with vertical sides arched over and with an inverted arch at the bottom. Like the open channel, they must follow the fall of the land, and cannot go up and down hills. In some cases, as in the Loch Katrine supply to Glasgow, the covered channel may take the form of a tunnel through rock. Covered channels should be adequately ventilated and have manholes at intervals for convenience of access. They can be of practically any form in section though usually as above described. They can, and no doubt will in the future, be constructed of reinforced concrete. The covered channel overcomes the objections given above for open channels, but still has the disadvantage that it cannot follow the undulations of the ground.

Pipe Water Mains. The advantage of using pipes is that the water can be conveyed at varying levels—up hill and down dale—

within reasonable limits. Pipes can therefore be laid in a direct line, with a covering of $2\frac{1}{2}$ to 3 feet of earth only. With rises and falls there will be accumulations of air at the "summits" and means of escape must be provided; otherwise the pipe will become air-locked and the flow retarded, with a danger of bursting the pipes. There must be no very considerable rises in the pipe line; if an imaginary line be drawn from the level of the water in the reservoir to the point of discharge of the pipe—termed the hydraulic gradient—the pipes must not rise more than 25 feet above this line and should preferably be kept wholly below this line.

Cast-iron Pipes. Cast-iron pipes are usually cast vertically in sand moulds with the sockets downwards, but a new method has been introduced in recent years, in which molten iron is introduced into a water-cooled steel mould, which is kept in rapid rotation; the iron is forced against the mould by centrifugal force and solidifies there. These pipes are denser, so that they can be made thinner without loss of strength, whilst the interior is smoother and probably less liable to corrosion. These "spun iron" pipes are now largely used for the smaller sizes of main, but for large mains vertically cast pipes are still universally used. The British Standards Institution have issued British Standard Specifications for iron pipes—B.S.S. No. 78 for the vertically cast and B.S.S. No. 1211 for those of spun iron.

Jointing Water Mains. The cast-iron pipes have almost always socket joints, though it is often convenient to use a flanged joint when a valve is to be inserted, as its ready removal is permitted for repairs if needed. All such pipes need to be protected against corrosion by the Angus Smith or other process, since not only does the rusting of the pipe reduce its strength, but it also makes the inside of the pipe rough and retards the flow, owing to the friction being greater.

Cast-iron pipes are usually jointed with caulked lead, i.e. molten lead poured into the socket and consolidated by means of a caulking tool. In recent years a material called lead wool has been introduced as a substitute for molten lead. It consists of skeins of fine strands of lead and can be readily used for work under water or other positions in which molten lead would be difficult to use. Fig. 147 shows a section through a caulked-lead joint suitable for a cast-iron aqueduct. It will be seen that the lead is "keyed" in, in order to make the joint more secure.

Flexible Joints. There are now on the market a variety of flexible joints and they are rapidly coming into general use. Their chief advantages are their flexibility, rapidity of laying, and the

fact that large excavations for joint-holes are unnecessary and these fully compensate for the extra cost of the joint. Their flexibility enables the pipes to be laid in curved routes without special bends and much reduces the danger of fracture in bad ground or from traffic vibration. One of several satisfactory joints of the kind is the Stanton mechanical lead joint shown in Fig. 149. A lead ring, in which a steel spring has been cast to distribute the pressure on the lead evenly, is placed over the spigot of the one pipe, which is then pushed into the tapered socket of the other. Two half collars, C in the illustration, fitted with two set screws, S, to each, are then tightened with a spanner, the lead ring becoming compressed and making the joint watertight. The lead ring is shown blacked-in in the illustration.

In the Stavely flexible joint the joint ring is of rubber, faced with lead, and this is pressed against a shoulder in the socket by a cast-iron ring, when the latter is tightened by bolts or wedges.

The Baxter pre-cast lead joint has lead rings cast in the inside of the sockets and the spigots are slightly tapered. When the spigot is forced home the lead is compressed and is finally caulked with tools.

Stanton Cornelius Joint. The jointing material in the Stanton Cornelius joint is merely a rubber ring, placed initially on the end of the spigot by rolling it up a wooden cone fitted to the spigot temporarily. When the spigot is pushed into a socket the rubber ring rolls relatively to both, so that it takes up its final position half-way down the socket, where there is a slight recess to receive it. This joint is very cheap and therefore suitable for rural supplies, where economy is of great importance. It cannot be expected to be as durable as the more expensive joints previously described, but a good quality rubber has a longer life than might be expected.

Steel Water Pipes. Steel pipes possess many advantages over cast iron; they can be much thinner, so that their weight, for the same strength, will be from one-third to one-fourth that of cast-iron pipes; they are obtainable in much greater lengths, so that the number of joints to be made is about halved; on these accounts their cost is less. They are especially suitable for use in ground liable to subsidence, on account of the greater elasticity of the metal. Their chief disadvantage is that steel is more liable to corrode than is cast iron. As a protection they are treated by the Angus Smith method and are wrapped on the outside with Hessian cloth, impregnated with bitumen, or covered on the outside with asphalt. These pipes have socket and spigot joints, which are

filled in the same manner as those of cast iron. The British Standard Specification for steel pipes is B.S.S. 534.

"Lined" Iron Pipes. A comparatively recent development is the introduction of "linings" of concrete or asphalt in the interior of both cast-iron and steel pipes, the lining being "spun" in by centrifugal action. Such means of protection are very efficient in preventing corrosion, but are somewhat costly.

Reinforced concrete is hardly ever used for water mains. Some very large mains were made under the "Bonna" patents many years ago, but the form of construction is too elaborate for its economical use in mains of ordinary or small size. A method has recently been introduced in which concrete is put into a rapidly rotating framework of reinforcement, placed inside a rotating mould, so that the concrete is spun into position around the reinforcing rods; this method may have a future for mains of considerable size, but the weak point of reinforced concrete for pipes is the difficulty of forming satisfactory joints at a reasonable cost.

Asbestos Cement Pipes. A new pipe that is particularly useful with water which has a corrosive action on iron is the "asbestos cement" pipe. These are made to withstand the same pressure as cast-iron pipes, but should not be used where settlement or vibration are to be feared, because they have not much longitudinal strength. They also have little or no resistance to a blow from a pick, which may easily occur when they have been laid in roadways near other pipes and workmen are excavating. They are cheaper than cast-iron pipes, especially if the latter would have to be lined to resist corrosion. They are particularly worth consideration for rural supplies.

This pipe has no sockets; an asbestos-cement collar is threaded over one of the pipes to be jointed and a rubber ring is placed on each pipe in such positions that when the collar is moved sideways to cover the joint it will roll the rubber rings to their proper places; finally the ends of the collar are usually pointed in cement-mortar to protect the rubber, unless the maximum degree of flexibility is desired, in which case the pointing should be omitted. There is a British Standard Specification (B.S.S. 486) for these pipes.

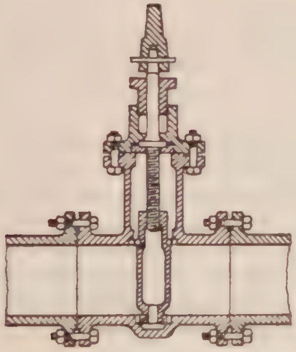
CHAPTER VII

THE BUILDING—ITS WATER SUPPLY
(continued)

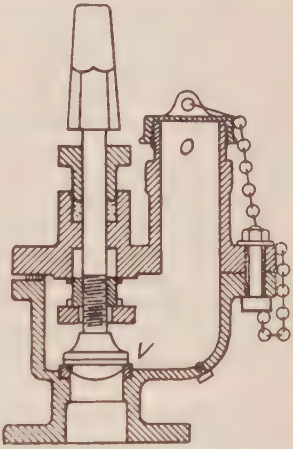
Distributing Mains. The distributing mains from the service reservoirs are laid along the streets, and should have not less than 2 feet 6 inches to 3 feet of covering over them since they must not only be deep enough to be safe from frost but also far enough below the road surface to be safe from injury from heavy traffic. They are usually of cast iron with caulked-lead or flexible joints, though flanged joints are sometimes used where valves occur, and should be protected against corrosion. The main from the reservoirs should split up into two or more as soon as possible, in order to diminish the area affected by accidents to mains, and everything should be done to ensure the limitation of the area affected by such accidents. It is done largely by the use of secondary mains, it being possible to throw the supply from one into the other. Dead ends to mains should be avoided owing to the possibility of stagnation; sharp bends and junctions should be avoided also, owing to the loss of pressure they cause.

Tests for Supply Pipes. The pipes should be tested to double the working pressure they will have to sustain. This is done in a hydraulic machine, the pressure being shown by a gauge; a few lengths of pipe can be put together for testing, so as to test the joints as well. The pressure in the mains should always be sufficient to discharge a stream of water well over the highest building in the district, except church spires and towers. A good working pressure is 80 lb. per square inch, which is equal to a "head" of about 180 feet, or a column of water about 180 feet high, but any head between 80 and 200 feet would be reasonable.

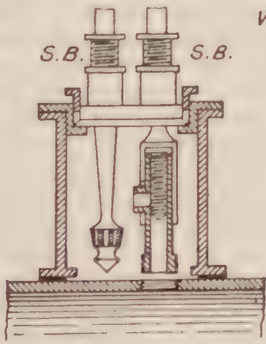
Valves on Water Mains. Sluice valves are placed on the mains at distances of 800 to 1000 yards and at the commencement of each branch main. They have cast-iron bodies and are made to suit either flanged or socketed pipes. The seatings, or contact parts of the valve when closed, are formed of gunmetal. Fig. 157 shows a vertical section through such a valve, fixed to the main by flanged joints. The spindle is of bronze and its top is square to receive a key, the turning of which raises or lowers the sluice by



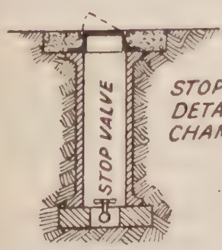
GATE VALVE
157



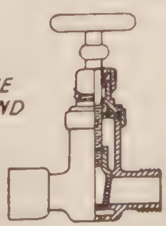
WATER HYDRANT ON MAIN
158



APPARATUS FOR DRILLING, TAPPING AND ADDING A BRANCH SERVICE TO MAIN UNDER PRESSURE
159



STOP VALVE DETAILS AND CHAMBER
160



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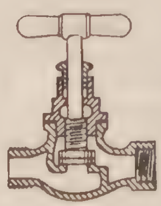

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means of the screw shown. Cast-iron valves are used even if the pipes are of steel or asbestos cement. Their form and dimensions have been standardised in B.S.S. 1218.

Hydrants. Hydrants are placed on all mains at intervals of about 200 yards, for the purpose of fire extinguishing, filling water-carts and for emergency supplies during severe frost, enemy action and the like.

A hydrant consists of a short vertical branch from the main, usually controlled by a screw-down valve, V, as shown in Fig. 158. The outlet end O has a screwed end to fit the standard hose couplings in use in the locality. When not in use a cap is kept screwed on this end, to keep out dirt. When required for use the cap is removed, the hose screwed on and the valve then lifted by turning the vertical spindle. The whole fitting is placed in a chamber below street level, access being obtained through an iron cover.

Formerly "ball" hydrants were much used, in which a gutta-percha or vulcanite ball was held up by the water pressure against a metal seating; by screwing on a stand pipe to the fitting, the ball was forced down and the water allowed to rise in the stand pipe. The chief drawbacks to this type are that leakage is easily caused by grit getting between the ball and the seating and that dirt may get into the main; they are now not allowed by the Minister of Health and the screw-down type, previously described, is much to be preferred.

Intermittent Water Supply. Occasionally it is the practice to turn on the water for only a limited time each day. This necessitates the installing of a large storage tank (perhaps 300 gallons or so for a household of six persons) to act as a reserve when the supply is off. Such a system is called an intermittent system; it is unsatisfactory from many points of view and is now seldom adopted except for small supplies to isolated houses or small groups of houses where the water has to be pumped; in such cases it is convenient to pump only for a few hours daily.

The Constant System. Apart from such cases the constant system, in which the water is always turned on, is almost universal in this country. A cistern is necessary in each house for supplying sanitary fittings and the hot-water service, in case the supply is cut off temporarily for repairs to mains, but it can be much smaller than where the supply is intermittent.

Tapping Water Mains Under Pressure. When laying on water to a building it is unnecessary to shut off the water in the public main, there being appliances in use for making the connection,

between the supply pipe to the house and the main, under pressure. The principle in these appliances will be understood from the diagrammatic section given in Fig. 159. It shows merely the principal parts of the apparatus, omitting the details. It consists of a watertight box which can be attached to the main by means of a chain or straps, a watertight joint being made with a washer. It has a revolving horizontal cover carrying two "stuffing boxes", SB, equidistant from the centre about which it revolves. Through one of these a combined drill and "tap" (or threader) is put, and through the other a connecting ferrule with a branch.

The hole is drilled and tapped, and the cover then resolved to bring the ferrule over the hole, into which it is screwed. A screw-plug is fitted to the ferrule and this is kept screwed down so as to close the branch, as shown, until the house service is laid on.

It can be unscrewed and left in the threaded extension at the top of the ferrule permanently.

In the most recent machines there is only one spindle instead of two. After this has been used to drill and tap the hole, it is withdrawn far enough for a valve to be closed underneath it. The cover can then be removed and the ferrule put on the spindle in place of the drill and tap. The cover is then fastened down, the valve opened and the ferrule screwed in.

Material for Service Pipes. The service or supply pipe to the building may be of various materials. For fairly hard water lead is the most suitable, it being strong, pliable, made in long lengths, necessitating few joints and not likely injuriously to affect the water. Lead is liable to be corroded when in contact with cement, lime or certain woods, such as oak; the pipes therefore should be wrapped in bituminous felt where they pass through walls or are in contact with timber.

Ternary Alloy of Lead. An alloy of lead, known as ternary alloy, is likely to be used extensively in the future. Not only is it less likely to crystallise and become brittle through prolonged strain, but it is so much stronger than lead that it can be of one-third the thickness, on which account the cost will usually be less. It is less liable to be attacked by acid water and it is as easily jointed as ordinary lead pipes.

Galvanised Iron Pipes. Iron pipes, made from puddled iron in preference to steel, are often used for hard waters, but they should be protected from corrosion by galvanising, which consists of coating them with molten zinc by dipping them in a bath of that metal. Other preservative processes are also used. Iron pipes are cheap, but have the disadvantage that they cannot be bent,

so that proper bends and angles have to be used. For soft waters a patented tin-lined iron pipe, known as the Health pipe, has also been much used in recent years.

Light-gauge Copper Pipes. Copper pipes of light gauge also have been much used lately; though rather more costly than iron in the first case, their longer life and lower cost of upkeep makes them economical. They are cheaper than lead because they are very much thinner. They are specified in B.S.S. No. 659.

The sizes of service pipes are largely governed by the water companies' regulations, which usually prescribe the maximum diameters for the various cases, a pipe of ½-inch internal diameter being the usual size for an ordinary dwelling-house. If the supply is intermittent, the diameter must be greater, a ¾-inch pipe being about the equivalent. Lead pipes are made in lengths, or coils, of 60 feet up to a diameter of 1 inch, and from 1¼ inch up to 2 inch diameter in coils of about 40 feet. The following table gives suitable weights for service pipes of various diameters:

Lead Service Pipes off Mains							
Internal diameter in inches . . .	⅜ in.	½ in.	⅝ in.	¾ in.	1 in.	1¼ in.	1½ in.
Weight in lb. per yard	5 lb.	6 lb.	7½ lb.	9 lb.	12 lb.	16 lb.	21 lb.

The British Standard Specification 602 (for lead) and 603 (for ternary alloy) specify thicknesses for various diameters, subject to different pressures.

Iron pipes are of three grades, known as "gas", "water" and "steam" strengths respectively, increasing in weight and thickness in the order given. For pipes subject to the pressure of a water authority's supply, the steam quality should be used.

Soft Copper Tubes. Where water has to be "laid on" from a main to a distant farmhouse or similar building in a rural area and over pasture or arable land, it is possible to use soft copper tubes brought on to the site in continuous coils around a wood drum, without the expense of digging a trench. Pits are excavated at intervals to agree with the length of pipe on the coil, and an adaptation of the "mole" plough drawn by a tractor, while a knife-edge makes a vertical slot in the earth at the bottom of which the "mole" (a torpedo-shaped fitment) makes a tunnel through the

earth just big enough to take the pipe, while a braided steel wire stocking shaped fitment grips the free end of the copper tube and draws it after the mole through the tunnel until it reaches the second pit.

The process is now repeated from pit 2 to pit 3, etc., until the objective is reached. and the loose ends are then jointed up with compression joints or with capillary soldered joints. This method shows a great saving in labour where the conditions are suitable, as the tractor and mole plough can pull coils up to 200 feet long and up to 2 inches in diameter through the soil, reducing both the cost of excavation and much of the expense of jointing.

Plastic Pipes. Plastic tubes of "Alkathene" are another fairly recent innovation which appear to promise well. They can be obtained in coils up to 500 feet in length and can be jointed by standard metal fittings of the compression type, and they are said to stand the strain of tractor and mole-plough treatment. They may be specified with confidence for cold-water service pipes in domestic work. for waste pipes and for warming pipes. They are flexible and will not burst when water freezes and are more frost-resistant than metal.

The service pipe is laid from the main to the building at a reasonable depth, which should not be less than 2 feet 6 inches to ensure protection from frost and traffic. It is also an advantage to place it in a tarred wooden trough. filled with pitch, or other bituminous compound. but this is seldom done.

Stop Cocks and Valves. Just outside the building a stop valve should be placed. In most districts this is placed in the path just outside the consumer's boundary, but in others it may be found that the Water Company's regulations permit it to be placed in the front garden. It should be protected and made readily accessible by the construction of a small chamber. Fig. 160 shows a section through a suitable form. It consists of a stoneware pipe of special shape, 6 to 9 inches in diameter, supported on two bricks, and carrying a cast-iron hinged cover and frame. The cover can be surrounded. for protection, with a small block of concrete, or a small stone slab can be fitted round it. Another stop valve should be inside the building.

Types of Stop Valve. There are many forms of stop valve, but the best is that with a "sluice" valve, as this permits of an uninterrupted flow when open. For inside use they usually have a controlling handle or wheel, but for external use they should have a loose key or handle to prevent interference with them. The more frequent use of stop valves on the internal services can be a

great advantage (see Fig. 187) though in low-price housing, this is often restricted to one. Fig. 161 shows the construction of a stop valve of the sluice or "full-way" type, used only on pipes over 1 inch in diameter, and Fig. 162 an entirely different form. The mechanism will be apparent from the illustrations, but it should be noted that where likely to be interfered with, instead of the handle or wheel there would be a square end over which a loose key would fit. Outside valves should always have square heads. Stop valves have been standardised in B.S.S. 1010.

Interior Rising Main. On entering the building the pipes should be carried up the faces of internal walls, so far as possible, or in specially constructed pipe-ducts where they will be protected from frost.

It is better that pipes should not be buried in the plaster of a wall, and, if put in a chase or sinking formed especially to receive them, such chase should be of sufficient size to give ready access to the pipes. If wooden casings are used, the fronts should be secured by means of brass screws and cups, so that they are readily removable.

Minimum Fall. All water pipes should be fixed so that they have a fall towards the lowest point of the system, in order that they can be readily emptied for repairs, or as a protection against frost when the house is unoccupied, a draw-off tap being provided near the lowest point for this purpose.

Service Pipes. The arrangement of the service pipes depends on whether the constant or the intermittent service is the one in use in the district. Thus, if the constant service is in use, a minimum of cistern accommodation is necessary, sufficient only to supply the boiler of the hot-water service and the sanitary fittings during such time as the water may be temporarily shut off for repairs to the public mains, and for this purpose a tank of 60 to 100 gallons is generally adequate for the average six- or eight-roomed suburban house. In the intermittent service and in cases where the householder is dependent on his own supply, pumped to a storage tank by electric or petrol pump, a much larger cistern is necessary. For the intermittent system the capacity can be estimated at one day's requirements per person, while for the private supply three days' supply would be better, to tide over a period when the pump and motor need attention. A very usual allowance in this case is 25 to 50 gallons per day per person, so for a household of six persons the size might be 300 gallons and 900 or 1000 for the two cases mentioned. Generally speaking, the smaller the tank (so long as it is sufficient for its duty) the

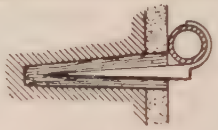
better, for too large a tank tends to accumulate sediment, from which no normal drinking water is entirely free. In addition to this disadvantage, the large storage tank usually has to be placed on the roof of an outhouse, owing to its size and weight, bringing further problems of protection from frost in winter, heat in summer and risk of pollution by vermin at all times of year.

In some cases, two cisterns are provided, one to supply water for drinking and cooking and another to supply the sanitary fittings, but this is an unnecessary refinement if the water fittings are of good quality and the W.C. cisterns have efficient ball valves.

Fixing Water Service Pipes. The pipes require to be carefully fixed to guard against damage. Iron pipes can be fixed by means of pipe hooks, an example of which is shown in Fig. 163, the pipe hook being driven into a wooden plug which has previously been driven into a small hole made in the wall Pipe hooks should not be used for lead pipes, as, if carelessly driven in, they are likely to cause damage to the pipes. An alternative is to fix the lead pipes by means of galvanised iron clips, as shown in Fig. 164, screwed into a wooden fillet or "ground" fixed flush with the face of the plastering. Wood plugs could be used but the wood fillet makes a better job. If a secure fixing can be obtained without the use of wooden plugs or fillets, the use of them should be avoided. Plugs often become loose by reason of shrinkage, unless they are made of very well-seasoned wood. The clips can also be of brass if preferred. Another method is to attach "tacks" of sheet-lead to the side of the pipe, by means of solder.

Fig. 165 shows an elevation and Fig. 166 a sectional plan of such a method of fixing, the tacks being marked T. A wood ground is shown, fixed to plugs driven into the wall, and the tacks, or lugs as they are sometimes called, are screwed to them. The sketches show a double tack, but single tacks are often used for small pipes. Tacks or clips, whichever may be used, should be about a yard apart.

Lead Pipes under Floors or in Lofts. As lead pipes have so little rigidity in themselves, they need some support when laid under floors or across the rafters in unboarded lofts or similar places. If they run parallel to the joists or rafters, they should rest on a batten or ledge, fixed to the timbers at a slight slope to permit the pipes to be drained if necessary. If they run across the joists, these should be cut away or drilled to make way for the pipe, with supports from joist to joist under the pipe to prevent sag. In the loft space, a length of floorboard or batten can be nailed across the joists to support the pipe.



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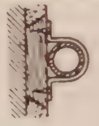

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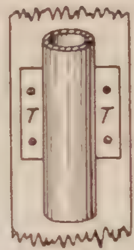

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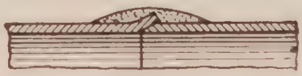

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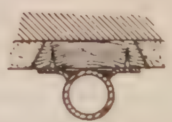

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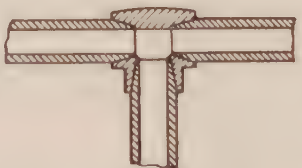

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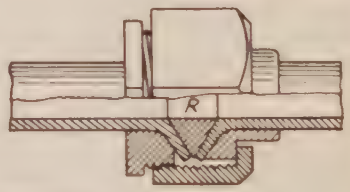

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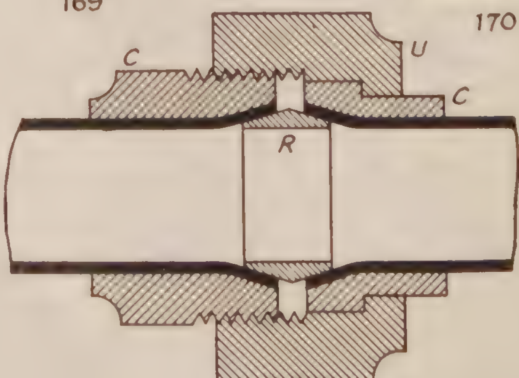

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Jointing Iron Water Pipes. The best method of jointing iron pipes is to have a screw thread on each end of each pipe and join the two pipes together by means of a loose iron collar having a thread internally; the threaded ends of pipes and inside of collar should be smeared with red lead, and a few strands of spun yarn, smeared with the same substance, should be wound round the threaded ends when the joint is made. In the case of joints underground, the exposed threads, after the joint is completed, should be painted with red lead for protection from rust.

Joints for Lead Service Pipes. Lead and lead alloy pipes for water should always be jointed by means of the plumber's wiped-solder joint. Fig. 167 shows a part section and an elevation of such a joint. The abutting ends are fitted together as shown, and a length of a few inches on each pipe is painted with a mixture of whiting, lampblack and thin glue, termed "soil"; the ends are then scraped lightly with a tool called a shaving hook. The remaining soil keeps the flux from flowing and gives a clean end to the joint. The solder is then poured on the joint and wiped with a special cloth to the shape shown, a part of the "soil" being left exposed to give a finish to the joint. Usually the opened end of the one pipe is rasped down for neatness of job.

Amalgaline Jointing. A method of jointing lead pipes in an entirely different way is that known as amalgaline jointing. There is no bulbous projection as with the wiped joint, the pipe being, externally, continuous in appearance, as shown by the section in Fig. 168. The two adjacent ends are fitted together, as in the sketch, by means of special tools. The abutting surfaces are then cleaned, and a strip of amalgaline wound round the end of the pipe marked A. Amalgaline is tinfoil coated with a mixture of stearine and vaseline and is used in the form of a ribbon 0·002 inch in thickness. The abutting ends of the pipe are kept close together while heat is applied by a blow pipe, the ribbon melting and the two pipe ends being fused together. Special fittings are needed for T junctions, as shown in Fig. 169, and special sockets are obtainable, if desired, for a joint on a straight length as in Fig. 168. In the latter case, the abutting ends of the pipes would both be shaped as at A in the figure, to fit the opposite ends of the socket. The method is simple, strong, neat in appearance and economical; the fact of its being simply and quickly made has prevented it becoming a favourite with the plumber and the joint has not proved a commercial proposition.

Another method of jointing lead pipes in an expeditious manner, such as for temporary work, is by means of special sockets, such

as shown in section and part elevation by Fig. 170. The adjacent ends are bossed out as shown and separated by a ring of triangular section, marked R; two other rings, one plain and one threaded, are placed outside, and the whole tightened up by a nut as shown. This joint, first introduced many years ago, did not have much sale. Since the introduction of compression joints for copper tubes, it has been put on the market again.

Jointing Drawn Copper Tubes. If copper tubes are used, they may be jointed by capillary soldered joints or by welding, or by the compression joint, an example of which is shown in Fig. 171, which is similar in principle to the joint of Fig. 170. The ends of the tubes are bossed out and the ring, R, put in between. The collars, C, one of which has an external screw thread, are placed over the tubes and they are drawn together by turning the union nut, U. This presses the ends of the tube tightly against the internal ring, R.

Service Tanks. The main pipe entering the building from the outside is termed the rising main. It passes up to the cistern, or cisterns, which may be either open or closed, and of various materials. The usual form is open.

The commonest form is that built up of riveted or welded steel sheets, the whole being galvanised after construction. The tops have turnover flanges to stiffen them, with stiffening plates at the corners. The inlet and outlet holes should be drilled before galvanising. These are relatively light, cheap and durable, unless the water is very acid, when corrosion soon takes place. Galvanised steel cisterns have been standardised in B.S.S. 417.

Galvanised cisterns should not be used if the pipes are of copper, as electrolytic action is likely to occur between the copper and the zinc coating of the cistern if the water contains free carbon dioxide.

Generally it is better that pipes, cylinder and tank should be in like metal.

Very large cisterns are sometimes built up of wrought-iron plates or of cast-iron sections, protected against corrosion.

The "Angus Smith" Process. In the case of cisterns built of cast-iron sections, the sections are usually flanged and bolted together, a tight joint being made by planing the abutting flanges and placing a packing of oakum between. The best protection against corrosion is given by what is known as the Angus Smith process. Immediately after casting, the parts are heated to about 600° F. and dipped into a heated solution (about 300° F.) consisting approximately of four parts of bitumen, three parts of prepared oil and one part of paranaphthaline.

Bower-Barffing. Another process is "Barffing", which consists of forming a coating of black magnetic oxide over the whole surface.

Wooden cisterns lined with lead, zinc, or copper were once largely used, but they have been almost completely superseded by the self-supporting type of galvanised iron or copper. They can be readily made of any shape to suit awkward positions, but have practically no other advantages. Lead and zinc are both quite unsuitable for the storage of soft water.

Slate Cisterns. Slate cisterns have no injurious effect on water, but are very heavy. They are constructed of slabs fitted together with grooved joints and strengthened by means of rods or bolts passing from side to side. The joints are made watertight by a paste made of red and white lead, but care should be taken that the water cannot come in contact with the jointing material. This can be prevented by brushing over the joints with bitumen. Glazed stoneware cisterns are very heavy, but, like slate, do not prejudicially affect the water. They are easily cleaned, owing to the glazed surface, but cannot be obtained of large size.

Protection of Drinking Water Tanks. All cisterns of the foregoing type should be covered with a tightly fitting wooden cover. All cisterns should be placed in well-lighted, ventilated, and easily accessible positions, so that they may be readily inspected, repaired or cleansed.

Tanks in Lofts. An unprotected loft is not an ideal place for a service water tank, but if it must be used to conserve space, the pipes should be kept away from the eaves and should be lagged with felt strip or other insulating material to safeguard them in frosty weather. The best way to "lag" the tank is to construct a casing of wood or asbestos cement sheets round it, leaving a 2-inch space which can be filled in with asbestos fibre, granulated cork or some other insulating material, taking care to see that the rising main where it rises from the ceiling joists to enter the tank at the ball valve gets equally satisfactory protection.

A useful way to protect the top of the tank is to use a metal drip tray such as is sometimes used in a garage under a car engine. This is generally about 2 inches deep and can be filled with the same type of insulation as that used round the tank and the size can allow a 2 inch margin so that it reaches the tank casing. The wood cover can then be omitted. Other precautions which should be taken against risk of damage by frost are:

(*a*) The service pipe leading to the house should be kept at a safe depth. The requirement varies with different water under-

takings' regulations, but to be safe, 2 feet 6 inches should be the minimum until well under the building.

(*b*) The rising main should be carried up in a pipe-duct inside the building or at least against an inside wall. If fixed against an outside wall, the pipe should be well lagged—behind the pipe as well as front and sides.

(*c*) Careful lagging or other protection of all pipes in roof space or other exposed places.

(*d*) Casing of cisterns as just described.

Ball Valves. The various inlets and outlets of cisterns next call for notice. The inlet to the ordinary open cistern takes the form of a ball valve, or automatic "tap". There are a great many varieties, a few of which will be described and illustrated.

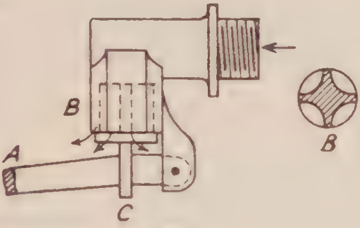
Ball valves are made for low, medium and high pressures. These are usually defined as follows:

Type	Approximate Water Head	lb. per sq. inch
Low . .	Under 90	Under 40
Medium .	90–230	40 to 100
High . .	230–460	100 to 200

The appropriate B.S.S. are Nos. 1019 and 1212.

The Croydon Valve. One of the oldest forms is that known as the "Croydon". The low pressure form of this valve is shown in Fig. 172, the lever being broken off at A to permit of the more complicated part of the ball valve being shown to a larger scale. The course of the incoming water is shown by arrowheads. A plug B is connected to the lever at C, and when the cistern is full the plug is held up tightly to prevent the admission of more water. The upper part of the plug B is shown in the elevation by dotted lines and in cross-section by the small sketch at the side. The cross-section of the plug is such that, when the ball falls, as it will do when water is drawn from the cistern, water is able to pass in from the rising main. This type of ball valve is still in extensive use, but it is only suitable for low pressures, is noisy, and is primitive in principle.

A "Croydon" high-pressure valve is shown in Figs. 174 and 175. In this case the outlet for the water, O, is smaller, a circular plug or piston being held up against it. The plug has a rubber washer, shown in black. From the section it would look as though there



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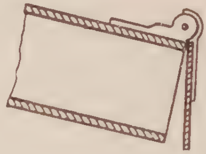
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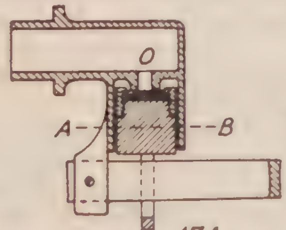

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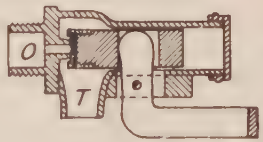

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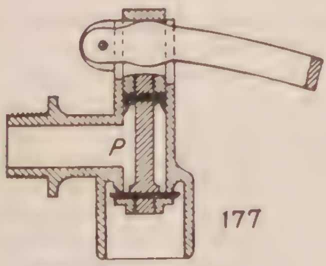

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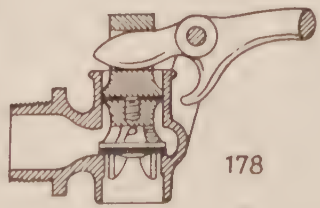

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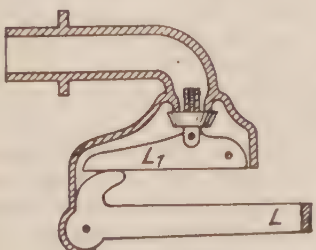

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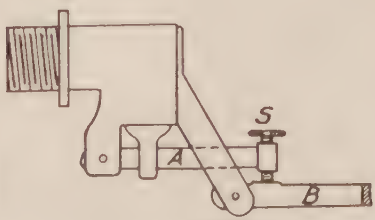

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was no way out for the water, but the section of the casing around the valve is in the form shown in Fig. 175. Like the low-pressure valve of this type, the high-pressure one is noisy, the water entering in two disjointed streams and, unlike other forms of ball valve, no method of silencing can be adopted.

The Portsmouth Valve. Another well-known form is the "Portsmouth" ball valve.

The high-pressure valve of this type is shown in Fig. 176, the plug being horizontal instead of vertical as in the previous example. It will be seen that the falling of the lever, as the copper ball at its end sinks, opens the waterway, O, and the water passes vertically downwards through a short tube, T. The screw cap at the end is for the purpose of obtaining access to the plug when it is necessary to fit a new washer. A recent development in ball valves is an interchangeable diaphragm, so that a corroded one can be renewed or "high" changed to "low".

This form of ball valve, or indeed any with a tube outlet, can be rendered silent in action by attaching a lead or composition pipe to the outlet tube, thus lowering the point of discharge to an inch or so above the bottom of the cistern. It will be seen that such a pipe could not be attached to a "Croydon" valve.

The Equilibrium Valve. The best kind of ball valve is that known as the equilibrium variety. The simplest form of such a valve is that shown in Fig. 177. The waterway is closed by a vertical piston, P, which holds up a leather or rubber washer against the outlet. At the upper end of the piston is another washer, in the form of what is known as a "cup" leather, so called from its shape, as shown in black in the section. In the two varieties previously described, the water is always tending to force the valve open, but in this example the valve is kept in equilibrium by reason of the fact that the water pressure is acting equally on the lower and upper washers. At the same time, the fall of the lever readily opens it and on rising closes it. Another example of the same type is shown in Fig. 178. It will be seen that the principle is the same though the construction is different. There is not the vibration and consequent wear on the valve in the equilibrium form that there is in others. This type is suited to both high and low pressures. Another form of equilibrium valve has a small-bore waterway leading to a water chamber beyond the plug so that water pressure is maintained on both sides while the valve is closed.

Another form of high-pressure ball valve is that involving the

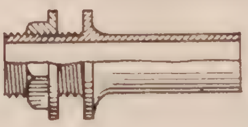
use of compound levers, arranged so that a very slight upward pressure on the copper ball exerts a considerable thrust on the valve. Fig. 179 shows a well-known variety of this type. It will be seen that a small force acting upwards at the end of the lever, L, would cause a much greater force to be transmitted to the end of the short lever, L_1.

Ball valves require occasional adjustment, due to the straining of the lever carrying the ball. This lever is of small section and is usually bent by the plumber in order to put matters right. To guard against the risk of breaking the lever by this practice, an ingenious arrangement, shown in Fig. 180, has been introduced. The lever is in two pieces, A and B, and the necessity of bending the lever is overcome by the provision of a small adjustable screw, S.

Having considered the forms of inlet to cisterns, let us next consider the outlets and the methods of connecting them. The outlets serving fittings should be connected to the side of the cistern, about a couple of inches above the bottom, so as to prevent any sediment that may accumulate from passing to the fittings. An overflow pipe should be provided in all cases, fixed just below the level of the inlet valve and discharging through an external wall in a fairly prominent position so as to act as a warning pipe, since this pipe will only come into use if there is anything wrong with the ball valve. In large cisterns a cleaning-out pipe should be provided, having its mouth flush with the floor of the cistern, controlled by a stop valve, and discharging through an outside wall and over a rainwater head.

The mouth of this pipe can be closed by a plug attached to a chain fastened near the top of the cistern, or a closed vertical pipe can be attached to the plug to enable it to be lifted out. Sometimes the case is dealt with by putting a trumpet-mouthed vertical overflow pipe, the lower end of which fits into the mouth of the cleaning-out pipe and so forms a plug. This is not a good practice, as it does away with the warning effect of the ordinary form of overflow pipe. Cleaning-out pipes and trumpet overflows are not permitted by most water authorities' regulations, but the former are none the less desirable.

Lead Safes. The lead safe sometimes placed under the cistern must have a waste pipe which should be carried through an external wall; it serves to collect condensation water from the sides and bottom of the tank in humid weather, thus preventing discoloration of the ceiling below which sometimes takes place due to this cause. It also serves the purpose of an additional



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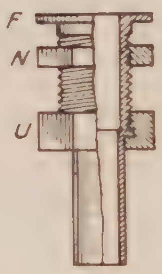

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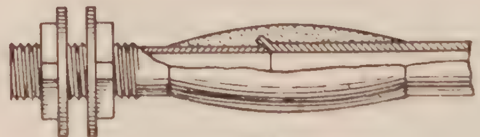

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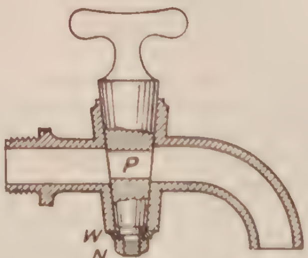

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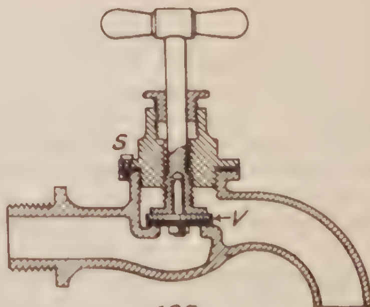

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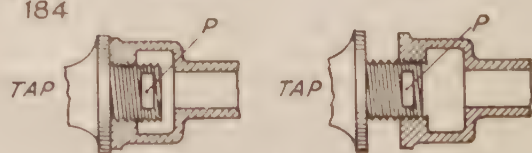

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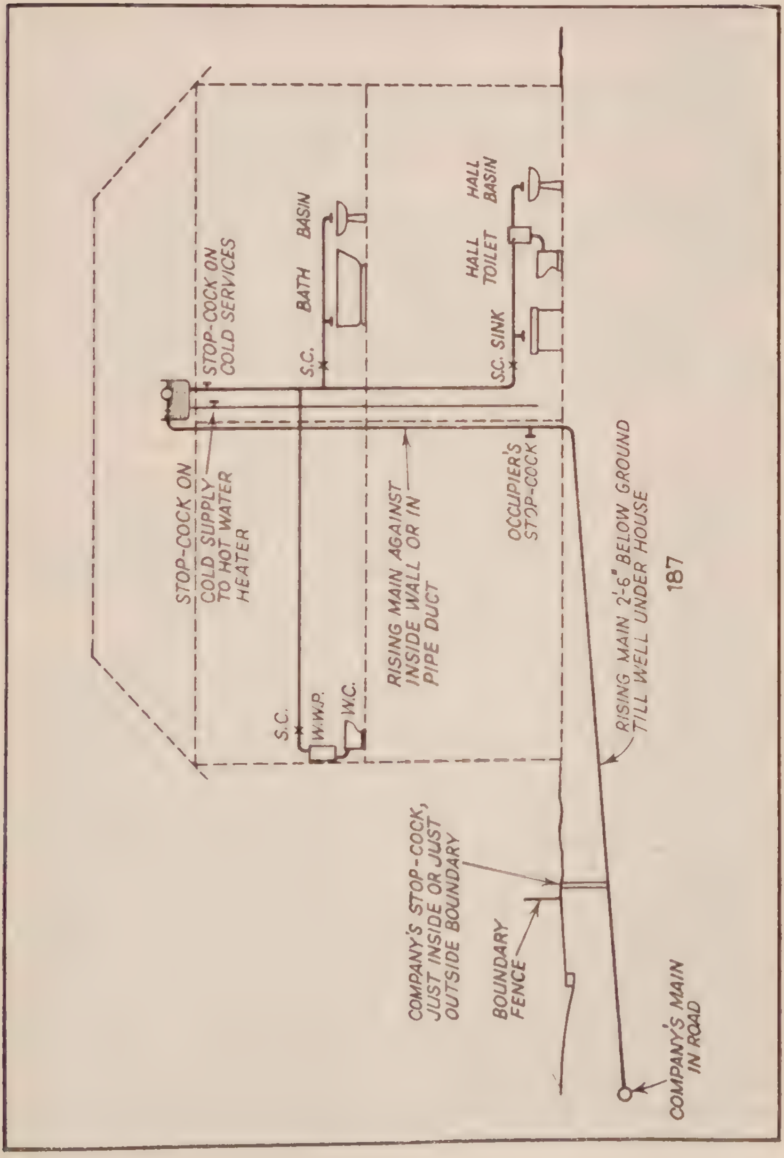
STOP-COCK ON
COLD SERVICES
S.C.
BATH
BASIN
HALL
TOILET
HALL
BASIN
S.C. SINK
STOP-COCK ON
COLD SUPPLY
TO HOT WATER
HEATER
RISING MAIN AGAINST
INSIDE WALL OR IN
PIPE DUCT
OCCUPIER'S
STOP-COCK
RISING MAIN 2'-6" BELOW GROUND
TILL WELL UNDER HOUSE
S.C.
W.W.P.
W.C.
COMPANY'S STOP-COCK,
JUST INSIDE OR JUST
OUTSIDE BOUNDARY
BOUNDARY
FENCE
COMPANY'S MAIN
IN ROAD

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warning pipe, since it only discharges when there is something wrong, and should therefore be discharging in a readily noticeable position.

Connections to Cisterns. Pipes can be connected to cisterns in various ways. Thus, Fig. 181 shows a part section and part elevation of an ordinary single-nutted boiler screw of brass. It is merely a short length of tube with a screw thread at one end, a flange abutting against the outside of the cistern and the nut securing it. A lead pipe would be attached to a boiler screw by means of a wiped-soldered joint, as shown in Fig. 183, which illustrates, also, a double-nutted boiler screw. The difference between this and the ordinary form will be apparent from the sketch.

"Boiler Screws" and "Screw Unions". The connection of a pipe, such as cleaning-out pipe, could be made by means of a flange washer, nut and union. Fig. 182 shows such fittings. The flange, F, would be fitted to the floor of the cistern, the screwed length to which it is attached passing through to the under side, where the nut, N, would secure it. The union, U, would then be coupled up to it, having been previously connected to a lead pipe by means of a wiped joint. A union joint also furnishes a means of connecting a lead pipe to one of iron. The connection between a copper tube and a tank is carried out with a fitting similar to Fig. 182, except that the shoulder nut, U, is replaced with a "compression" fitting of the type shown in Fig. 171.

The Warning Pipe (or Overflow). The end of an overflow pipe, waste pipe to a safe, or any similar item, should be finished with a hinged copper flap as shown by Fig. 173. The pipe is, of course, laid with a fall, and one frequently sees the end of it cut on the skew so that the flap shall fit closely to it. This is, however, a mistake, as in very cold weather a trickle through the overflow pipe would be sufficient to freeze the flap to the pipe and so close the latter. If constructed as shown this cannot occur, while the flap, owing to its light weight, readily closes should there be a tendency for cold air to rush into the room through the pipe.

Pipe Sizing. The sizes of the pipes also depend on circumstances. For lavatory basins, closet cisterns, and small sinks a pipe of ½-inch diameter is usual, while for baths, housemaids' sinks, large kitchen sinks, etc., a usual size is ¾-inch diameter. The main service pipe down from the cistern should be not less than 1 inch. It will be obvious, however, that the size of the establishment will always be one factor in determining the size, while, in the case of pipes branching off the rising main, the pressure in the pipes must be considered. The number of fittings supplied by each branch is

also a governing factor. Thus, with a moderate pressure a $\frac{3}{4}$-inch pipe will serve three $\frac{1}{2}$-inch branches, and a 1-inch pipe five branches, and so on in proportion to the cross-sectional areas of the pipes. The pipes should go from point to point by the most direct route possible, be placed on internal walls where possible, be covered where exposed, and be not less than 2 feet away from pipes carrying hot water.

Taps for Drinking Water. Supplies to taps from which drinking water is obtained should be taken from the rising main, as drinking water should not be taken from a cistern if avoidable. Lavatory basins should be supplied in the same way, as water is often drawn from them for cleaning teeth.

Service pipes from cisterns can be of lighter weight than is needed for service in direct communication with the public mains. The following table is a fair one for this purpose:

Lead Service Pipes from Cisterns.					
Internal diameter in inches	$\frac{1}{2}$ in.	$\frac{3}{4}$ in.	1 in.	$1\frac{1}{4}$ in.	$1\frac{1}{2}$ in.
Weight in lb. per yard .	5 lb.	8 lb.	11 lb.	14 lb.	18 lb.

All copper tubes for internal water services should be to B.S.S. No. 659.

Bib-taps. The draw-off taps over the fittings can be of many kinds. They are termed bib-cocks or bib-valves, as opposed to stop-cocks or stop-valves, from which water cannot, of course, be drawn. The simplest form is that known as the plug-cock, constructed similarly to a gas tap, which is, in fact, the only form correctly termed a bib-cock. Fig. 184 shows a sectional elevation of one. The handle forms part of a solid plug passing into and through a socket at right angles to the flowing water, the plug being secured by a washer, W, and nut, N. Through the plug a hole or port, P, is cut, which, when in line with the pipe, allows a through passage of water, while if the port is *across* the pipe no water can get through. This form of tap is simple in construction, but closes very rapidly, with the result that it leads to concussion or water hammer in the pipes, the increase in pressure caused thereby having often been sufficient to burst the pipe.

All water authorities' regulations prohibit the use of cocks on pipes which have the full pressure of the mains on them, and insist on the use of valves.

The same construction is adopted for stop-cocks, but the plug principle is not nearly so good as that of the screw-down bib-valve. Fig. 185 shows a section through a fitting of this kind. When the tap is closed the passage of the water is prevented by a small valve, V, which consists of a circular disc with a guiding pin above it and a washer of leather, fibre or rubber-asbestos composition, shown in black, below it. This valve is kept down by pressure exerted through the screwing down of the spindle, the stem of which has a cavity to receive the guide pin of the valve. The two main parts of the body of the tap are screwed together, with a leather washer between, and if the tap handle gets stiff it is possible that the sudden turning of it might unscrew the upper part of the body of the tap, to prevent which a small crew, S, is sometimes put through the two as shown. In time the washer of the valve requires renewing, which necessitates the shutting off of the water at the nearest stop valve and unscrewing the two main parts of the tap. The valve can then be lifted out and attended to. To obviate the shutting off of the water for this purpose an ingenious device has been introduced. The back of the tap is of special construction and it fits into a special connection. Fig. 186a will explain the detail of this. The screwed back of the tap is not open, as in Fig. 185, but closed, the water entering the tap through two opposite ports, marked P. When the tap is screwed into position as in sketch A, the water can pass through, but if it is necessary to renew the washer and the tap be partly unscrewed, as in sketch B, it cannot, so that the tap may be left as at B while the valve is taken out and attended to, and then screwed in again as at A. The form and dimensions of taps have been standardised in B.S.S. 1010.

The Kelvin Bib-valve. The trouble incidental to the frequent renewal of the washers of the ordinary form of screw-down bib-valve led to an ingenious form of screw-down tap being introduced by Lord Kelvin. Fig. 188 shows a section through the Kelvin bib-valve. There is no washer, the waterway being closed by a metal or vulcanite valve. The spindle controlled by the handle has a domical lower end fitting into a socket of nearly the same shape. Around the spindle is a spring of phosphor bronze, pressing on the outer edge of the valve. When the water is being turned on, the valve rises against this spring, which keeps the base of the valve parallel with its seat. When being turned off, the spindle rotates the valve on its seating and by this means always keeps the surfaces in contact true. Any water that may rise into the upper part of the tap during opening and closing is carried off by the

small tube shown in Fig. 188. This tap is rather more expensive than the ordinary models and is not often fitted.

Spring Lever Taps. Another form of tap is the self-closing or spring lever tap.

In this form a lever is tilted forward to turn on the water, the flow ceasing as soon as the hand (or foot in floor models) is removed. They are a little more complicated in construction than the standard bib-valve and a little more likely to get out of order. Their great advantage is that they save water and the tap cannot be left running through carelessness, but the older models were very apt to cause "water hammer" by shutting off the flow too suddenly. Modern forms have a tiny water chamber incorporated into the design which prevents the sudden closing of the tap and prevents any tendency to water hammer.

Water Hammer. One occasionally finds instances in which there are sharp rapping or knocking sounds in the water supply pipes, to which the name of water hammer is given. It is usually caused by quick-closing taps such as plug-cocks, or self-closing or automatic taps. If the taps are near the main, the nuisance is unlikely to occur, but it frequently occurs on long lengths of house services. It is occasionally caused by defective forms of ball-valve. The remedy is to substitute proper screw-down bib-cocks, or efficient ball-valves, as the case may be.

Buzzing noises in Water Pipes. A somewhat similar defect sometimes occurs in water pipes when the washer of a bib-valve is worn or the nut securing it is loose, or the "jumper" holding it in place is loose in its socket. Either of these faults may lead to uneven pressure on the washer when the tap is half turned on, so that the washer or jumper rotates or rocks so as to turn the water on and off rapidly, the succession of short sharp raps merging into a hum or buzz. A little attention soon remedies the fault and the matter is not serious.

Placing of Stop-valves. Fig. 187 shows the placing of stop-valves and the various other parts of a typical cold water supply system for a small suburban house.

The Hot-water Supply Service. It is next necessary to deal with the installation of hot-water services, beginning with the separate parts.

The Domestic Boiler. This may be an independent or "free-standing" type, or it may be a "back boiler" built in at the back of an open sitting-room grate, or made part of the design of a kitchen range. The independent boiler, such as is illustrated in Fig. 96, is generally preferred in modern homes, since a single-

purpose fitting can have its design concentrated on the production of hot water, leading to greater efficiency. Moreover, the more extensive use of gas and electric cookers has made kitchen ranges burning solid fuel almost obsolete in new houses, except in the case of slow-combustion cookers burning smokeless fuel, thermostatically controlled and with heavy cast-iron heat storage for the boiling rings on the top. Cookers of this class are frequently provided with a carefully designed boiler as an accessory.

Back Boilers. In small houses, a boiler is often placed at the back of the sitting-room open fire, either to form an auxiliary to a main boiler, linked up in tandem (as in Fig. 204) to a single cylinder or hot-water tank, or as the sole means of hot-water supply.

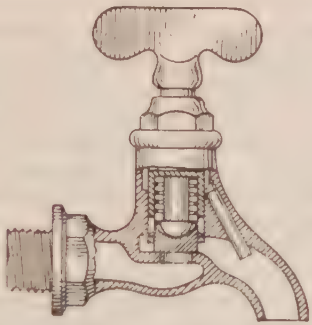
Most of the back boilers provided with modern day and night burning open grates are small cast-iron ones of rectangular shape and about 12 × 6 × 5 inches in size to hold about a gallon of water or a little more, and suitable to be used in conjunction with a 25- or 30-gallon cylinder. In the case of larger stores of the built-in but "openable" type, rather more latitude in design is possible, with the boiler designed to lean over the fuel box, or designed like a row of radiator sections, with the hot gases passing under and between the tubes. In slow combustion cookers and the older type of kitchen range burning bituminous coal, a "saddle" boiler like the front portion of Fig. 189 or a "boot" boiler of type shown in whole of Fig. 189 or 190 may be used, and the capacity may then be a little larger.

Construction of Boilers. Back boilers of the type just described, as well as the boiler portion mentioned in the preceding paragraph, are made of cast iron, welded wrought iron or of copper according to the circumstances and of the capital outlay possible.

Cast iron is cheap, but very liable to fracture in quick changes of temperature.

Welded wrought iron is the material most favoured. If the building served is in a soft acid water area, it would be wise to use a copper boiler, or to use a "Bower-Barffed" iron boiler, generally described simply as "Barffed". This process consists in heating up the iron work to a dull red and subjecting it to a jet of superheated steam, which gives the iron a coating of black magnetic oxide very resistant to any further corrosion.

Boilers should be provided with "hand-holes" or "manholes" with cover plates bolted on, to enable period removal of sludge or scale deposited from the water if hard. Scale is more easily removed from a copper boiler than from one of iron, but the cost is



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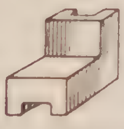

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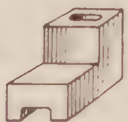

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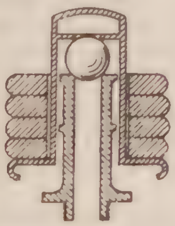

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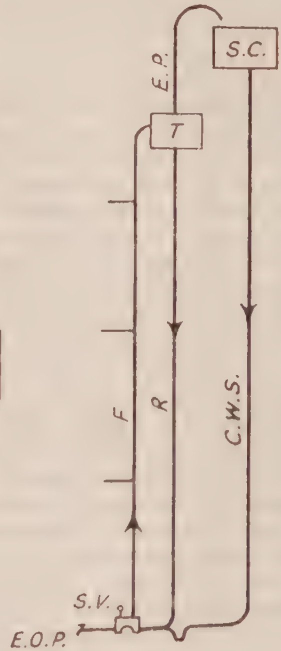

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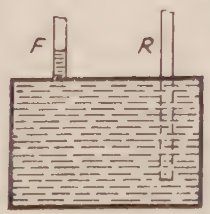

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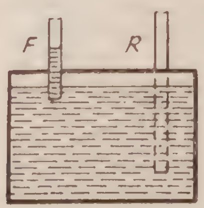

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considerably higher. If the boiler is of copper, the cylinder and pipes should be in copper also.

Hot-water Tanks and Cylinders. In some systems of hot-water supply the storage vessel is placed fairly high up in the building, and in such case it usually takes the form of a closed rectangular tank. If placed low down, however, the pressure in the vessel is much greater, and it is necessary to use a closed cylinder, since a vessel of that shape is much stronger. In either case the storage vessel is built up of iron plates riveted or welded together, the vessel being galvanised after the necessary holes have been cut, to protect it from corrosion. The thickness of the plates will depend entirely on the height of the cold-water cistern above the storage vessel. Both cylinders and tanks are made of plates either $\frac{1}{8}$ inch or $\frac{3}{16}$ inch thick, or for smaller sizes or less pressures, a thickness of either 16, 14 or 12 B.W.G. (Birmingham Wire Gauge). Thicknesses of copper cylinders are set out in B.S.S. No. 699, while for copper tanks 22 S.W.G. is the minimum. Hot-water tanks and cylinders are usually marked with the permissible working head, in feet of water.

"Manholes" in Tanks. Every cylinder and tank should have a handhole, not less than 6 inches diameter, for access, preferably at the side, closed by a cover. The joint between the cover and the vessel can be made in various ways, but it should be remembered that the cover is intended to be removable without great trouble. One method is to use a rubber washer, blackleaded on its lower side to prevent its adhering to the iron; another is to use a a cardboard ring, set in a soft putty made of red and white lead and oil; a third is to use two thin layers of putty with a thin layer of strands of hemp between. Tanks and cylinders are standardised in B.S.S. 417.

Tanks and cylinders should be put in positions which are as little exposed to cold air as possible, but, if this presents difficulty, they should be protected, to prevent loss of heat, by encasing them with a material such as asbestos cement.

Hot-water Service Pipes. The pipes used for conveying hot water should be galvanised wrought-iron welded steam tubing or copper tubing. Iron pipes should be jointed with red-lead cement and fixed at least 2 feet away from pipes conveying cold water. There should be no right-angled elbows in the course of the pipes, bends being used instead, so as not to impede the circulation of the water. The pipes can be fixed by means of either wall hooks, iron clips or straps, or by special iron clips of such shape that the pipes are kept well away from the face of the wall.

If placed in any position in which they are likely to come into contact with cold currents of air, as in a corridor, the pipes should be protected against loss of heat by either a spiral winding of strips of hair felt secured at intervals with wire, or by silicate cotton attached to canvas strips and secured by wire in the same way.

Cold W.S. Pipe. The cold-water supply pipe to the system can be of iron, copper or lead. Stop-cocks or valves used on the hot-water service should be of the full-way type, to prevent impeding the circulation. Great care is needed in reference to such stop-cocks or valves. They should have loose keys, kept only in the hands of a responsible person, as should a stop-cock be closed and left so, grave danger of explosion may occur.

The Expansion Pipe. From the particulars given later as to the arrangement of the pipes, it will be seen that there is a sort of natural safety-valve to a hot-water service in the form of an expansion pipe and also in the form of a cold-water supply tank. Both of these items may, however, unless the system is most carefully arranged, fail by the action of frost, and it is therefore usual to provide a safety-valve of a more definite type. The reason for this is readily seen. If a hot-water service is sealed, the temperature of the water may rise much above 212° F., the temperature at which water boils under atmospheric pressure, and its consequent expansion may be so great that the boiler or the pipes may be ripped open, the issuing water being converted to steam on meeting the air. If there are any stop-cocks on the service, a safety-valve should always be used, in case the system should be bottled up by the unauthorised closing of one. Another possible cause of explosion in hot-water work is the blocking up of the pipes, or any part of them, by the deposit from hard water, but accidents from this cause are unusual, as the reduced efficiency gives ample warning that all is not well.

The Safety Valve. The safety-valve can be placed on a short special pipe communicating directly with the boiler, or one of the ordinary pipes, called a return, just near the boiler; or, best of all, directly on the boiler.

There are several kinds of such valve, such as the spring, lever, deadweight, diaphragm and fusible plug. In the case of the spring safety-valve, a cylindrical brass case has a valve at the bottom, and a screw cap at the top with a hole through it. Passing downwards through this hole is a vertical spindle with an enlarged conical point resting on the valve. Around the spindle, between the enlargement of the conical point and the underside of the screw

cap, is a spiral spring, the strength of which can be regulated by screwing in or unscrewing the screw cap. This type of safety-valve is unreliable. As generally constructed, the surfaces in contact between the valve and its seating are too large and liable to become firmly stuck together.

The lever safety-valve is a regular item in connection with steam boilers, but it is cumbersome and unsightly in a hot-water service. It consists of a valve held on its seating by a lever having an adjustable weight at its end.

The deadweight safety-valve is the best for a hot-water service. It is simple in construction, compact and efficient. In its usual form, the surfaces in contact are very small. It will be seen from Fig. 191 that the pipe is closed by a ball held down by a casing carrying a number of circular weights. From the smallness of the surface in contact with the ball there is no danger of the valve sticking, whilst even if this did occur, the surfaces would break apart under far less pressure than would be necessary to burst the boiler or pipes.

The so-called diaphragm safety-valve is not really a valve at all. Between two short lengths of pipe or tube a sheet of mica, thin copper, or lead is placed, closing the outlet. The thickness of such sheet or diaphragm is proportioned so that it is the weakest spot in the system, and gives way when there is danger of an explosion. In the case of the fusible plug safety device, which also is not a valve in the true sense of the word, a plug of fusible alloy is placed in a brass case, the plug being of such a nature that it melts at a temperature slightly above boiling-point, and in this way affords relief to the dangerous pressure that would be existing in the system at such a temperature.

All the pipes of a hot-water service should have a fall in order that the system can be emptied, if required, by means of a special draw-off tap provided for the purpose.

The methods of arranging the pipes can be best shown in a diagrammatic way, and in studying the following sketches it must be remembered that pipes shown passing from point to point in a straight line do not necessarily follow that course in actual work, it being necessary to determine the routes of all pipes according to the circumstances of each case, such as the fittings to be served and their relative positions, the impossibility of carrying pipes through certain rooms, and so on. The pipes should, wherever possible, be run so as to necessitate only short branch pipes to the fittings.

There are three principal methods of arranging the parts of a

hot-water service. known as the tank. the cylinder, and the combined tank and cylinder systems. there being, of course, variations of each. There are many differences of opinion among hot-water system fitters as to the best method of executing certain minor details of the work in any system, but the broad principles of each system are well established.

The Tank System. Fig. 192 shows. diagrammatically, the arrangement of the parts of the tank system as ordinarily carried out. The boiler, is fitted with a safety-valve, S.V., and provided with an emptying out pipe, E.O.P., to enable the whole system to be emptied. From the boiler a flow pipe, F, rises to a storage tank. T. near the top of the building, a return pipe, R, completing the circuit of the water between the boiler and tank. Provision must be made for the expansion of the water on being heated, and an expansion pipe. E.P., is provided, leading from the top of the tank. It can be taken through the roof, or, if a cold-supply cistern is near. it can be turned over that, as shown. In either case it should rise at least 1 foot higher than the supply cistern. Its end is open, but if the system is well arranged water rarely issues from it. The cold-water supply is laid on by a pipe, C.W.S., and can be connected to the boiler as shown, or to the tank, or to the top of the return pipe. This is largely a matter of economy and individual preference.

The branches to the fittings should be taken from the flow pipe.

The dip shown on the cold-water supply pipe, C.W.S., is used to prevent the hot water circulating into such pipe.

Direct connection of the cold water to the tank, T, sometimes leads to cold water being drawn from such tank.

Hot-water Circulation. The phenomena of water circulation have already been dealt with under the heading of hot-water warming, and it is sufficient to add that they can be easily studied by anyone who is sufficiently mechanical to make a small model of glass pipes and flasks, with the aid of rubber corks and tubing, applying the heat from the flame of a candle.

It will be noticed that the flow pipe is taken from the top of the boiler and the return connected to the side low down. If this side connection is difficult for some reason, the return pipe may be carried down through the top of the boiler, but it must be prolonged downwards to give the right direction to the circulation. Fig. 193 shows a section through a boiler with the pipes so connected. The flow pipe, F, should be finished flush with the underside of the top of the boiler to prevent any accumulation of air or steam. Thus, in Fig. 194 the flow pipe is shown wrongly

connected, with a space between the surface of the water and the underside of top of boiler. The rising water would compress the air and the pressure might be sufficient to do serious damage. Similarly the expansion of the water, on heating, would greatly compress the air, with the same possible result. A further objection is to the noise of the bubbling water when steam forms in this cavity.

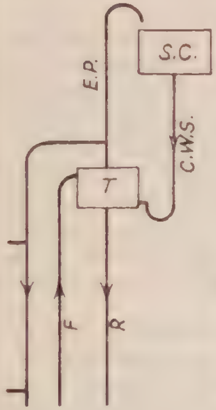
Reversal of Flow near Taps. It is important to remember that the conventional circulation of water in a gravity hot-water system is upset when a tap is turned on. The normal force of gravity of water flowing in both directions to reach the tap, overcomes the weaker force of convection. It is therefore desirable to tap only such pipes, and those only in such places, as will give a hot supply. Thus, in Fig. 192 it will be obvious that hotter water will be obtainable from the flow than from the return pipe. Also that hotter water will be obtainable at the highest of the three branches shown, as it is near the storage tank. The boiler is relatively small compared to the tank, and the water would be forced through it fairly quickly if a tap were opened on the lowest branch shown and left open for a while.

The Expansion Pipe System. Fig. 195 shows the "Expansion Pipe System" in which all the draw-off taps are taken from the base of the expansion pipe. It has the advantage, in small compact buildings where all the fittings to be supplied are near to this point, that all the hot water ready can be drawn off before any cold water begins to emerge, but it has obvious disadvantages in a larger house, where fittings are scattered over a wide area, as the branch lead has to be emptied of cold or tepid water before hot water from the tank can flow.

Long H.W. Branches Without Return. Most water companies and boards object to a hot-water branch without a return, if 20 feet or more long, owing to the consequent waste of water.

Fig. 196 shows (on the left) an undesirable method of connecting the cold-water supply as it will mix too freely with the hot water. The method on the right is much to be preferred. Connection to the hot-water tank instead of the boiler will often save plumbing.

The Tank System. The disadvantages of the tank system are (1) the water has to travel some distance before reaching the storage tank, so that a good supply is not very quickly obtained; (2) there is a certain amount of heat lost by radiation from the flow and return pipes and from the surfaces of the tank, if, as is often the case, it is put in a roof or cold cistern room; on the other hand, the system has the advantage of (1) relative cheapness compared with



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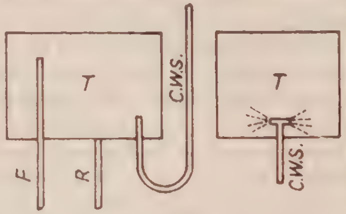

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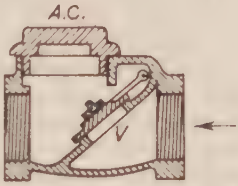

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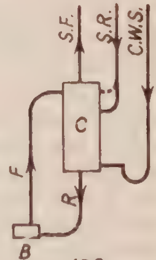

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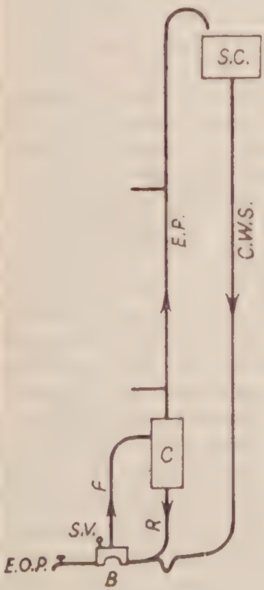

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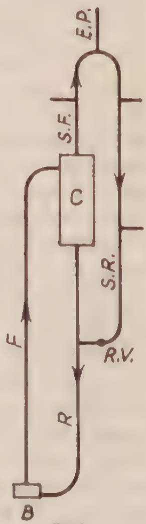

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other systems, and (2) a good supply of hot water to fittings which are high up in the building.

The Cylinder System. The cylinder system, in which the cylinder is placed relatively low down in the system, ensures a good supply to the lower fittings, but often a poor one to those high up. Hot water is obtained in less time than with the tank system. There is greater safety where water in the cold-supply cistern is liable to run short, it being impossible to empty the cylinder through the draw-off taps, as ordinarily arranged, since they are all above the cylinder. The flow and return pipes are shorter and there is therefore less loss by radiation on the way to the storage cylinder; further, the cylinder is generally put in a warmer position than a tank, usually in the kitchen.

On the other hand, the system is rather more costly than the tank system and the cylinder has to stand a higher pressure.

Fig. 199 shows an expansion pipe system using a cylinder near the boiler. It is suitable for a house of moderate height provided the fittings are close together, branches being taken from the expansion pipe to them. It will be seen that the hot water will rise in this pipe to approximately the level of the water in the supply cistern a little higher actually, for hot water weighs less than cold.

Fig. 200 shows a more extensive form of the cylinder system, provided with a secondary flow and return taken round past the various fittings so as to supply them by means of short branches. Branches are taken from both flow and return pipes of the secondary system of circulation, the secondary flow being marked S.F. and secondary return S.R. The position of the connection of the secondary return to the cylinder is of importance. If the house is small, it will be an advantage to make this connection within 4 inches of the top of the cylinder, as shown by dotted line, by which means it will be possible to get a small supply of hot water in circulation around the building in a very short time after the fire is lighted, this water not mixing with the main body of water in the cylinder. In blocks of flats, hotels, etc., where large quantities of water may be wanted at the same time, and where the fire is probably burning slowly all night, the connection may be a foot or so lower, as shown by full line. The letters already used will be adopted in the remaining illustrations to obviate full description in each case. In the remaining examples, also, the safety-valves and cleaning-out pipes are omitted, in order to keep the sketches simple, but they would, of course, be used, as in the cases already dealt with. Fig. 198 shows the method of connecting the C.W.S.

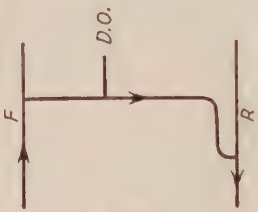
pipe to the cylinder instead of the boiler, but here, again, as with the tank, it might enter the bottom of the cylinder. To save making two holes through the chimney breast, the flow and return are often brought through the same hole, both entering the side of the cylinder low down, but in such cases the flow pipe must be carried up some distance inside the cylinder.

Reflux Values. It is sometimes difficult to find a position for the cylinder in the kitchen or near the boiler; it is then put higher in the building, and branches may be required both above and below it. Fig. 201 shows how this can be arranged, the secondary return being joined into the main return. In such case, to prevent relatively cold water being drawn from main return, a reflux, non-return, or back pressure valve is placed at R.V. The construction of such a valve is shown in Fig. 197. A light valve of copper is hinged so as to open readily, but also close readily against any attempted back flow of water. An access cap is provided at the top to enable inspection and repair of valve as necessary. A reflux valve of this sort sometimes proves a little noisy.

The secondary flow and return pipes are sometimes at opposite sides of the building, and it is necessary to run a pipe from the one to the other, as shown in Fig. 202. In such a case, the slight fall generally available for the pipe is insufficient to ensure a good circulation through this extra pipe, and matters are put right by giving the pipe a "drop" as shown, the greater density of the water at lower part of drop increasing the velocity of flow through the pipe. D.O. is the draw-off.

A method adopted sometimes is shown in Fig. 203, consisting of the addition of a by-pass pipe, B.P., from the main flow to the secondary. The object of this is to give a quicker hot supply than would otherwise be obtainable, by letting a certain amount of water escape going through the cylinder. Such by-pass must, however, be of considerably smaller section than the other pipes, or the whole of the water will be short circuited and not pass through the cylinder.

Additional power is sometimes given to a hot-water service by using two boilers, say perhaps a back boiler behind a sitting-room grate and the other an independent boiler in the kitchen or scullery, though usually the addition of an independent boiler of sufficient size makes the back boiler superfluous. The method of arranging the connections in such case is quite simple, and is shown in Fig. 204. The flow from the second boiler is joined to that of the first, and the return of the second also joins the return of the first. Each boiler would have its own safety-valve and emptying pipe.



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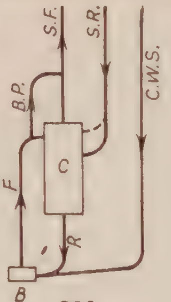

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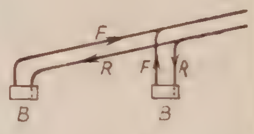

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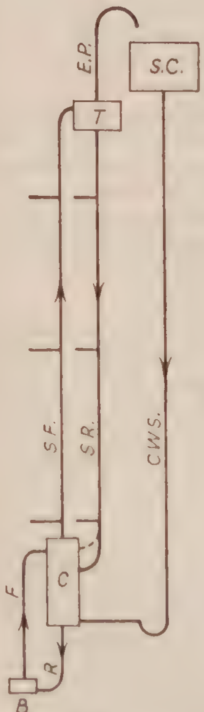

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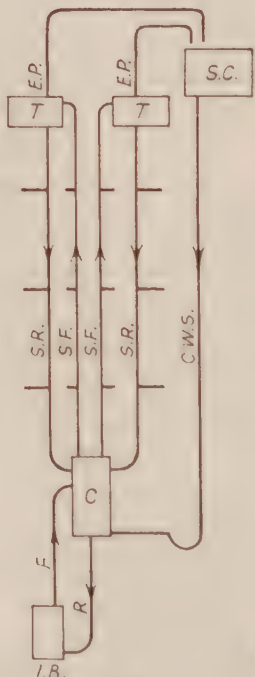

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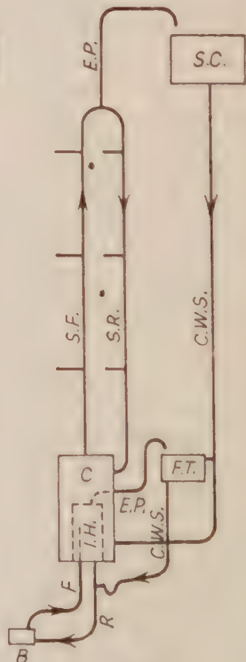

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Combined Tank and Cylinder System. The third principal system is the combination of tank and cylinder shown in Fig. 205. It is a system possessing the advantages of both the tank and cylinder systems and also overcoming the disadvantages of both. The general arrangement will be seen from the sketch. The C.W.S. pipe can be connected to the tank, the cylinder, or the boiler, the usual practice being to connect it to the cylinder, as shown. This method of arranging the service gives a good supply of hot water to all the fittings, whether up or low down. It is, of course, better to take branches from the flow pipe only, if this can be conveniently arranged. The combined capacity of the two storage vessels would be made about equal to the capacity of the cylinder which one would use if the cylinder system only were adopted.

An extension of the combined system is shown in Fig. 206, there being two sets of secondary pipes. An ordinary range boiler would be inadequate for so large an installation, so an independent boiler, I.B., is shown. The expansion pipes would be at opposite sides of the building, and could either be passed through the roof or turned over a cold-water cistern if one should be near enough.

Indirect System. All the systems just referred to are examples in which the water is heated directly by the boiler. If the water of the district is very hard, there will be a considerable deposit of lime in the pipes and boiler. The deposit does not occur, however, if the water is not raised to boiling-point. A method of indirect heating can therefore be used on the lines shown in Fig. 207. The cylinder is double, i.e. a small one placed within a larger one, the small one being used as a means of heating the water by contact, and the supply to the fittings not passing through the boiler. Thus there are two complete systems in one. The boiler has the usual main flow and return pipes connecting it to the small cylinder, or indirect heater, which has its own expansion pipe. The water supplied to the fittings is passed through the main cylinder and around the heater, but the temperature does not exceed about 180° to 190° F., whereas water does not boil till 212° F. is reached.

Cold water must be laid on to both the boiler and the cylinder, and this is best done by means of a small feed tank, F.T., as the less the height of the feed tank above the heater, the safer is the main body of water from boiling. If there is difficulty in obtaining room for a sufficiently large indirect heater, the difficulty can be overcome by constructing it with cross tubes through which the main body of water can pass, thus increasing the heating area.

Instead of the indirect heater in the form of a cylinder, a coil of pipes can be used on the principle of the calorifier.

Extensive hot-water installations can also be worked by means of steam calorifiers, before referred to in connection with warming, and consisting of steam coils placed in cylinders, the hot-water supply being thus obtained without the use of boilers in the sense in which the word applies in the foregoing notes, but these are not suitable for private houses.

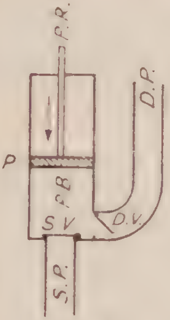
Size of Pipes. The sizes of the pipes, tanks, etc., must depend on the facts of the particular case, but, generally speaking, main flow and return pipes run from 1 to 2 inches in diameter, secondary $\frac{3}{4}$ to $1\frac{1}{2}$ inches, expansion pipes $\frac{3}{4}$ to $1\frac{1}{2}$ inches, branches to fittings $\frac{1}{2}$ to $\frac{3}{4}$ inch, and the cold-water service $\frac{3}{4}$ to $1\frac{1}{2}$ inches. The cold supply should be of good size in all cases, it being better to have it too large rather than too small.

W.S. Pumps. It would be beyond the scope of this work to deal in a very detailed way with the means of raising water to a height, but a few brief notes may be of interest. The means referred to may be summarised under the following headings: (1) Reciprocating pumps, such as lift pumps and force pumps; (2) steam pumps; (3) centrifugal and other rotary pumps; (4) the air lift pump; and (5) the hydraulic ram.

The Lift Pump. Fig. 212 gives a diagrammatic section through a lift pump. Passing down into the water of the well is a suction pipe, S.P., having at its foot a strainer or rose, the sum total of the areas of the holes in the strainer being equal to not less than twice the sectional area of the suction pipe. Above the suction pipe is the pump barrel, P.B., opening out of which is either a spout or a pipe termed a delivery pipe, D.P. Working up and down in the barrel is a piston or bucket, B, controlled by a piston rod, P.R., the latter being actuated by either a pump handle or a cranked axle. The bucket has a valve, B.V., and there are also valves at the upper end of the suction pipe, i.e. the suction valve, S.V., and at the lower end of the delivery pipe, i.e. the delivery valve, D.V.

A valve is also usually placed at the foot of the suction pipe, and termed a foot valve, F.V. Its purpose is to prevent water running out of the suction pipe when the pump is not working, thus making it easier to start the pump again.

The Common Suction Pump. The suction pipe cannot be of unlimited length, since the water rises in it by atmospheric pressure on the surface of the water in the well. During fine weather and in static conditions, the atmospheric pressure will support a column of water 34 feet in height, but in the case of moving water



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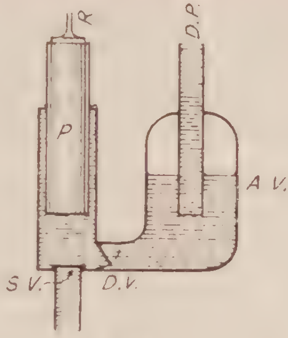

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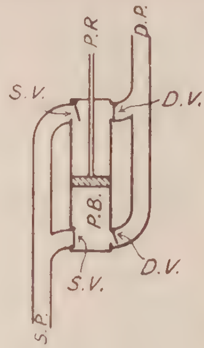

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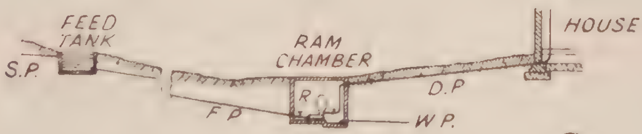

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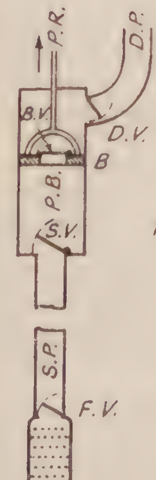

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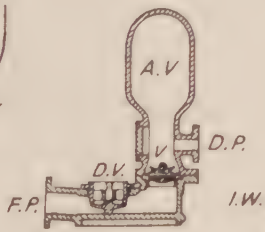

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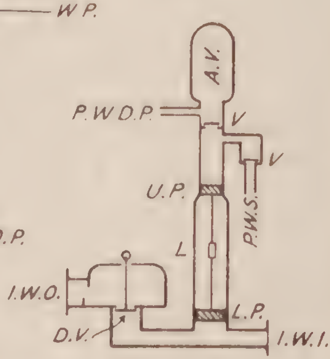

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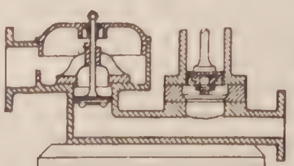

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the height is taken as about 25 feet, to allow for friction in the pipes, resistance of valves and low barometer. This means that when the rose or strainer is immersed below the lowest working level of the water in the well, there should not be a greater distance than 25 feet between the top of the bucket and such lowest working level, and it is preferable to keep this distance not more than 22 feet.

Briefly, the action of such a pump is as follows: As the bucket is raised, there is a tendency to cause a partial vacuum in the part of the pump barrel below it. The water consequently forces open the suction valve and rises into the space below the piston. As the bucket descends, the pressure closes the suction valve and opens the bucket valve, allowing the water to pass to the upper side of the bucket. On the bucket again rising it lifts this water, which forces open the delivery valve and passes up the delivery pipe, the delivery valve closing again on the descent of the bucket. If the delivery pipe is replaced by a spout, there is, of course, no valve such as that marked D.V.

If the well is more than about 22 feet deep, the pump barrels have to be placed in it, and piston rods extended to the top. The pump barrels are supported on joists, with a small platform to facilitate access, and the piston rods are kept in a true line by means of guides in the form of anti-friction wheels.

Two pump barrels may be placed side by side, served by a common suction pipe, and serving a common delivery pipe, the bucket of the one going down as that of the other goes up.

The Force Pump. A force pump, or as it is sometimes termed, a lift-and-force pump, is shown diagrammatically in Fig. 208. In this case the piston has no valve in it, and the entrance to the delivery pipe is at the bottom of the barrel. The reason for this will be obvious, as no water can pass to the upper side of the piston. The arrowhead shows the piston to be descending, in which case the pressure will close the suction valve, open the delivery valve, and force water up the delivery pipe. On the piston rising, the weight of water in the delivery pipe will close the delivery valve. The suction valve will open and admit more water, and the whole process will be repeated.

The Plunger Pump. Another kind of force pump is that shown at the left-hand side of Fig. 209. In this form the piston takes the shape of a solid plunger, P, of almost the same sectional area as the barrel. It will be seen that its action is similar to that shown in Fig. 208, the plunger displacing a certain quantity of water each time it descends and forcing it into the delivery main.

A careful study of the foregoing brief notes will show that the discharge of a pump would, unless means were taken to prevent it, be occurring in intermittent jerks, instead of a continuous supply. This is obviated in various ways. At the right-hand side of Fig. 209 is an air vessel, in the top of which air is imprisoned. The air acts as a cushion, being compressed as the water rises in the vessel when the delivery valve is open and expanding again when the delivery valve is closed. This expansion of the air forces a certain quantity of water up the delivery pipe when the plunger is not doing so and so makes the supply more continuous. The air also absorbs shock.

Air vessels require to be carefully proportioned, and means should be adopted for making good the loss of air from the vessel, which occurs by the water absorbing some of it and carrying it up the delivery pipe. This adjustment is made either by a valve of special form, termed a snifting valve, or by means of two small taps, one at the top to let the air in and the other at the bottom to let some of the water out.

The Double-acting Pump. Another method of obtaining a continuous supply is to use a double-acting pump. Thus, Fig. 210 shows a diagrammatic section of a double-acting force pump, the action of which is as follows: As the piston descends, the lower suction valve closes and the lower delivery valve opens, water being forced up the delivery pipe. While this is occurring, water is entering the pump barrel above the piston, through the upper suction valve, the upper delivery valve being closed. As the piston rises the upper delivery valve opens and the upper suction valve closes, water entering the barrel below the piston, to be displaced on the next descent of the piston.

The Bucket and Plunger Pump. A variation of the foregoing pumps is that known as the bucket-and-plunger pump, a combination of the suction and force pumps. The piston fills the sectional area of the barrel, and has valves in it, but the piston-rod is enlarged to half the sectional area of the barrel, to act as a plunger on the up-stroke.

With large pumping plants, steady and continuous delivery is obtained by working three pumps, side by side, the plungers being worked from the same crankshaft by means of three cranks set at 120° to one another; the pumps thus work in even rotation.

Steam Pumps. Steam pumps are of many patterns, but the principle involved is that of driving the water out of the pump barrel or chamber by the admission of steam, a good example being the pulsometer pump.

Centrifugal Pumps. Centrifugal pumps are entirely different in principle. The water is drawn by suction into the axis of a casing which is volute or spiral-shaped. Inside the casing is a wheel with blades fitted all around its circumference. The blades just clear the inside of the casing at that part of the spiral which is nearest to the centre, so that there is ample room for water elsewhere. The wheel is kept in rapid rotation, usually by an electric motor; it drives the water around with it and the centrifugal force, due to the water's rotation, causes the water to pass up the delivery pipe, which is tangential to the spiral casing. Centrifugal pumps are very efficient for lifting large volumes of water through small lifts, but are less efficient for high lifts.

A point of importance to note is that a centrifugal pump of ordinary type cannot be started unless it is full of water. To ensure that it remains full of water, when not in action, it is often submerged in the well. When this is not done a foot valve must be placed on the suction pipe to prevent the water running back down the suction; this valve must be kept in good condition or it will leak and trouble will then result. An additional precaution sometimes taken is to dip the delivery pipe from the pump below water level before taking it up the well; if this is done the apparatus will be kept full of water by siphonic action even if the foot valve is a little leaky. As in the case of other pumps with suction pipes the length of the suction should not exceed about 22 feet.

Certain improved types of centrifugal pump are now on the market, which are "self-priming" and the starting of which presents no difficulty, even when they become emptied.

Air-lift Pumps. The principle of the air lift for raising water is that of reducing the weight of a column of water by means of compressed air. A pipe is passed down the well to a greater depth below the water than the height the water is to be raised. Compressed air is admitted to the bottom of this pipe, but does not *mix* with the water in the ordinary sense of the word mix. The effect is to form thin layers of air and water in the pipe, with a resulting decrease in density, the water in the well or borehole acting downwards to force this lighter mixture up through the tube. It will be seen that air-compressing plant is needed for this method of raising water, the method being therefore only applicable to work on a moderately large scale, and then only in cases in which there is a considerable depth of water in the well. The appliance is inexpensive, simple in operation and reliable; it is, however, very inefficient as compared with many other forms of pump and this makes it unsuitable for work on a really large scale.

In view of the fact that it is not the best type for either small or very large plants, it is not surprising that this form of pump is almost obsolete.

For small installations, such as those for a private house or group of smaller dwellings, or a farm, where skilled mechanics are not available and it is not economic to allot one man's time to caring for the plant, it is all-important to choose a pump which is simple in character and reliable in operation, efficiency being of less importance. For large installations, such as those of a public water authority, efficiency is the chief factor to be considered: there is always skilled labour in attendance for repacking glands, remedying leaky valves, etc.

Hydraulic Rams. Hydraulic rams are often used in connection with the supply of water to large country houses. The principle underlying their construction is that of using the momentum of a body of water falling through an inclined pipe to raise a smaller quantity of water through a height. There are both "single-acting" and "double-acting" hydraulic rams. The former type is that in which the water lifted comes from the same source as the water utilised for driving the ram, while in the latter the water lifted is pure, and that used for driving the ram is impure, or at any rate of doubtful quality.

Fig. 211 shows an outline section of the arrangement of a water-supply system in which a single-acting ram is used. A feed tank of watertight construction, furnished with a strainer and grit chamber, is fed by a supply pipe, S.P., from, say, a stream. From the feed tank a feed pipe, F.P., or, as it is often termed, a drive pipe, passes to the ram, which will be dealt with more in detail later. The ram passes a small proportion of the water into the delivery pipe, D.P., but the bulk of it into the waste pipe, W.P., the latter quantity being used to work the ram.

Fig. 213 shows a section through a ram. There are many makes of these, varying much in detail, but all alike in principle. The water enters from the feed pipe at F.P., the feed pipe being a comparatively large one. D.V. is a dash valve, whose weight is very little greater than the water pressure due to the head of water behind it; hence, when the water is at rest in the pipes, the valve falls and water flows out through the valve to waste. As the velocity increases, the impact of the water on the valve closes it, and the momentum then opens the valve, V, admitting water to the air vessel, A.V. There the air is compressed, and its reaction, in expanding, forces the water up the delivery pipe, D.P. When the momentum is expended the valve, V, will close, the water

will surge back in the ram, causing the pressure in the ram to fall below that of the atmosphere, and the valve D.V. will open.

Water again escapes at the dash valve and the whole cycle of events occurs again, and continues so long as the supply is maintained. The length of the feed pipe should not be less than the height it is desired to raise water above the ram. To prevent damage by shock it is essential to keep air in the air vessel. As air tends to be carried away in the delivery stroke, a "snifting valve" should be fitted in the ram below valve V. to admit a small quantity of air when the rebound of the water causes pressure to fall below atmospheric.

The Double-acting Ram. A diagrammatic section of a ram on the double-acting principle is shown in Fig. 214. It is really a combination of a ram and a pump. The pure water enters the pure water supply pipe, P.W.S., and passes through a valve into the space above the upper piston, U.P. The impure water enters the lower part of the apparatus, through the pipe marked I.W.I. and passes on to the dash valve, D.V., working this part on just the same principle as with the single-acting ram, except that when the dash valve closes, the impure water does not rise higher into the apparatus, but merely exerts its force on the underside of the lower piston, forcing it up and so displacing the pure water into the pure water delivery pipe. The upper and lower pistons are connected by means of a rigid rod, through which a weighted lever passes at L. to facilitate the downward movement after the pure water has been displaced. In this case, also, the cycle of events continues so long as the supplies are kept up.

The pistons must of course be tightly fitting to prevent the passage of impure water. Fig. 215 gives an enlarged and more detailed section of the lower part of the apparatus, showing by a thick line the cup leather put to the pistons to ensure this result.

The Hydrostat Ram. An improvement on the hydraulic ram is the hydrostat, manufactured by Hydrautomat Ltd. In this there are two cylinders of widely different diameters, one vertically over the other, their pistons being on one common vertical piston-rod, so that movement of the one entails similar movement of the other.

In the large cylinder, water, which will be referred to as the driving water, is admitted alternately above and below the piston and is exhausted from the other end to waste, or to some house or district situated at a lower level.

In the smaller cylinder, water, which we shall refer to as the driven water, is admitted, either from the same source or from another source of purer quality, and is forced to the high level at which the supply is needed, either to a reservoir or direct to the consumers.

The entrance of the driving water to each end of the large cylinder, and its exhaust from the other end, are automatically controlled by an ingenious moving valve appliance. The entrance and exhaust of the driven water to and from the smaller cylinder are controlled by ordinary lift valves.

The superiority of the hydrostat over the hydraulic ram lies in the fact that it is noiseless in action, less liable to wear and tear, and more efficient.

Not only is it useful for lifting water from a stream for the supply of an isolated dwelling at a high level, but it is also much utilised for "boosting" up pressure in certain mains of public water supplies. The driving water in such a case is the water which is supplied to some low-lying district and is not run to waste, whilst the driven water is that which is needed for the supply of some district which is abnormally high in level.

The appliance is quite automatic in action, and will adjust its rate of working to the amount of driving water available and to the amount of driven water being consumed. It is unnecessary to provide a reservoir at the high level to receive the driven supply, unless the maximum rate of consumption at the high level exceeds the maximum rate at which the hydrostat will work, which of course depends upon the amount of driving water available.

Power Required for Pumps. Before concluding this chapter it would not be out of place to explain how the power required to pump water can be calculated, for which purpose a numerical example will be worked.

It will be supposed that it is required, during the hours at which the pumps are to be worked, to raise 1500 gallons per hour through a height of 160 feet.

One gallon of water weighs 10 lb., so that the weight lifted per hour is 15,000 lb., and the weight lifted per minute is $\frac{15,000}{60} =$ 250 lb.

Horsepower output of pump $= \frac{Wh}{33,000}$, where W = weight in lb. lifted per minute and h = lift in feet; so that in the present instance the horsepower output of pump

$$= \frac{250 \times 160}{33,000}$$

$$= \frac{40}{33} = 1\tfrac{1}{4}.$$

The engine required to drive the pump must have more power than this, since the efficiency of small pumping plants seldom exceeds 60 per cent. Taking the efficiency in the present case as 40 per cent.,

$$\text{Power output of pump} = \frac{40}{100} \times \text{horsepower of engine.}$$

$$\therefore \text{Horsepower of engine} = \frac{100}{40} \times \text{power output of pump.}$$

$$= \frac{10}{4} \times 1\tfrac{1}{4} = 3\tfrac{1}{8}.$$

In the above example it has been supposed that the delivery pipe is of ample diameter, so that the frictional resistance therein does not appreciably increase the head against which the pump has to work.

CHAPTER VIII

The Building—Its Sanitary Fittings and Waste Pipes

Architectural students and others wishing to study sanitary appliances and the necessary plumbing in greater detail than can be done in this chapter are recommended to refer to the B.S. Codes of Practice. No. 305 (Sanitary Appliances). No. 3 (Chapter 7, Engineering and Utility Services) and Post-War Building Study No. 4 (Plumbing). all obtainable from H.M.S.O., and available on loan at most public libraries. The Institute of Plumbers "Minimum Specification" prepared for the use of their members and available at the Institute, 81 Gower St., London, W.C.1, may also be useful.

Soil and Waste Water. There are three classes of liquid waste matter to be removed from buildings, namely the discharge from water closets, urinals, slop-closets, generally described as "soil"; that from baths, lavatories, sinks, etc., known as waste water; and rainwater from roofs, paths and paved spaces, described for drainage purposes as "surface water" or "rainwater".

(Incidentally there is a good deal of misuse of the term "lavatory" among certain sections of the general public. It should, as its name implies, be used for the wash basin or the room in which it is housed, and not applied to the water closet, as is so often done.)

"*Soil*", if not properly dealt with, can lead to very unpleasant insanitary conditions.

"*Waste Water*" is usually just dirty water, or water carrying small particles of food from washing up, cooking operations and the like. This needs removing from the house, but the risk of unpleasant odours is not so great.

"*Surface Water*" may carry soot or bird droppings from the eaves gutters or grit from gullies in garden paths or paved spaces (if so drained) but is otherwise cleansing in its action on rainwater pipes and drains rather than the reverse.

It is important to keep these definitions clearly in mind, because most local authorities in this country differentiate between them, and expect "soil", "waste water" and "rainwater" to be kept separate until they reach the underground drains (if any), where

they flow down together to the sewer or other place of disposal. These details will be referred to in later chapters.

"Dry" and "Water Carriage" Systems. In dealing with the first of the three classes of waste matter, that is the soil or excremental matter from buildings, there are two principal systems, known respectively as the "Conservancy" or "Dry" system, and the "Water Carriage" system. The former involves the use of earth closets, chemical closets or privies, and the latter, water-closets, drains, sewers, cesspools, etc.

In sparsely populated country districts the use of earth-closets and privies is permissible where no convenient position can be found for a cesspool, and where there is no regular public supply of water, but they should not be permitted in populous districts, as their use is against the best interests of health. All waste matters should be removed from the vicinity of the building as speedily as possible.

The conservancy system has been common in the towns of the north of England and the Midlands, where sanitary progress was less rapid than in the south, but even in the northern towns privies and earth-closets have now been almost entirely superseded by water-closets. A plentiful supply of water is essential to the success of any system involving water-closets and drainage, and where this cannot be obtained a good form of chemical closet or earth-closet is the best.

Waste Water and the Conservancy System. When the "dry" system is in vogue for the soil, it is generally necessary to install waste pipes, drains and a cesspool to deal with the waste water and either a "soak-away" or an underground storage cistern for the rainwater, details of which will be given later.

Privies with Middens. The earliest form of closet, or privy, consisted merely of a seat placed over a shallow pit termed a midden. The midden was sometimes lined with brick, slate or stone slabs, but was more often unlined, and was furnished with no means of deodorising the waste matters. More modern forms have either a fixed or movable receptacle, the latter system forming what is termed a pail-closet.

Pail Closets. Special pails are sometimes provided by the local authority, and periodically removed in special vans, being replaced by clean ones. The pails are emptied and disinfected before being used again. The space under the seat, whether furnished with a pail or not, should be of watertight construction, and the seat and riser should be readily removable.

Privy Ashpits. In some places the privy is combined with an

ashpit, the two being constructed back to back and communicating below the seat. A special shoot conducts the ashes so that they fall on to the foul matter and act as a mild deodorant.

Local By-laws as to Privies. By-laws vary from district to district, but the following list gives an average set of requirements in districts where privies are permitted.

1. The entrance to be from the open air.

2. To be not less than 40 feet from any well, spring, etc., used as a source of drinking or domestic water.

3. Ready means of access for cleansing.

4. Apartment to be properly lighted and ventilated into the open air, near the top.

5. Floor to be not less than 3 inches above ground, of non-absorbent material, and falling ½ inch to 1 foot towards the door.

6. Space beneath seat to be lined with non-absorbent material, and the floor of it to be not less than 3 inches above ground.

7. If a movable receptacle is provided, its capacity is not to exceed 2 cubic feet or, if a fixed receptacle, 12 cubic feet.

8. The space below seat must have no communication with any drain and not to be exposed to rainfall.

9. The privy is not to be less than 10 feet from any building used for a dwelling or place of business; and lastly, it is usual to require some provision for the application of dry earth or ashes from time to time in the case of a privy having a fixed receptacle.

Earth Closets. A much better apparatus is the earth-closet, which, like the privy, can have either a fixed or movable receptacle, the latter being very much to be preferred. Fig. 216 shows the arrangement in diagram form. In either case provision is made for the systematic application of dry earth to deodorise the discharges, which is best done automatically. There are many kinds of earth-closet, the best being those in which the earth is applied merely by the weight of the user on the seat actuating a series of levers. The earth should be of a loamy, vegetable nature, sand or gravel being of little value as a deodorant. The application of suitable earth turns the excremental matter into a sort of mould, suitable for use as a fertiliser.

Local By-laws as to Earth Closets. The usual official requirements for earth-closets are the same as for privies, with the addition of the requirement that there shall be a receptacle for dry earth or other suitable deodorising material with suitable means of application. Also the 10-foot distance rule is usually dropped and the earth-closet may be built attached to the building so long as there is no possibility of direct access of air from the E.C. to the rest of the house.

Chemical Closets. Chemical closets, illustrated in Fig. 217, possess distinct advantages over earth-closets. Earth is no more than a mild deodorant, whereas in a chemical closet powerful disinfectants can be used and these, in a well-designed apparatus, will render faeces and urine nearly, if not quite, sterile and absolutely inoffensive. They require less frequent attention and emptying than earth-closets and do not form a breeding place for flies and vermin. It is important, however, that the apparatus shall be so designed as to bring the disinfectant into intimate contact with every part of the sewage and with any surface liable to be fouled.

Perhaps the earliest type of chemical closet to be placed on the market was the "Elsan", which is available in portable and tank models. The portable model has either a vitreous-enamelled seamless steel or galvanised sewage container of 5 to 7 gallons' capacity, which, under normal household use, will need to be emptied daily or every few days according to the number of persons using it. Around the container is a steel ventilation chamber, which is preferably ventilated by a 3-inch diameter pipe passing through the roof, or through a wall or window, with a cowl at its top: there are also small air inlets in the sides of the chamber. Smaller models having no ventilation pipes are available, which are thus more portable. The top of the container is provided with an enamelled guard to prevent urine from passing into the ventilating chamber; the container has a handle to facilitate emptying. The seat and lid are usually of bakelite with chromium-plated hinges. Before use, a quart or two of water, mixed with a measure of specially prepared chemical liquid, is placed in the bottom of the container. No further attention is needed until the container is full, when the contents can be buried, or mixed with lime and leaf mould and used as manure.

The chemical used in the portable model is a liquid, the most part of which is miscible with water, but which contains a small amount of an ingredient which floats on the surface and, it is claimed, forms a smell-preventing seal.

The tank model is a permanent fixture, intended for schools, sports pavilions and the like. Either one, two or three white-glazed earthenware pans, each ventilated by a 4-inch diameter pipe, are connected to a cylindrical tank, placed underground beneath the apartment or apartments, of capacity ranging from 40 to 210 gallons, according to requirements.

As the lid is raised from the seat an anti-splash plate is automatically raised to a position which will prevent faeces falling

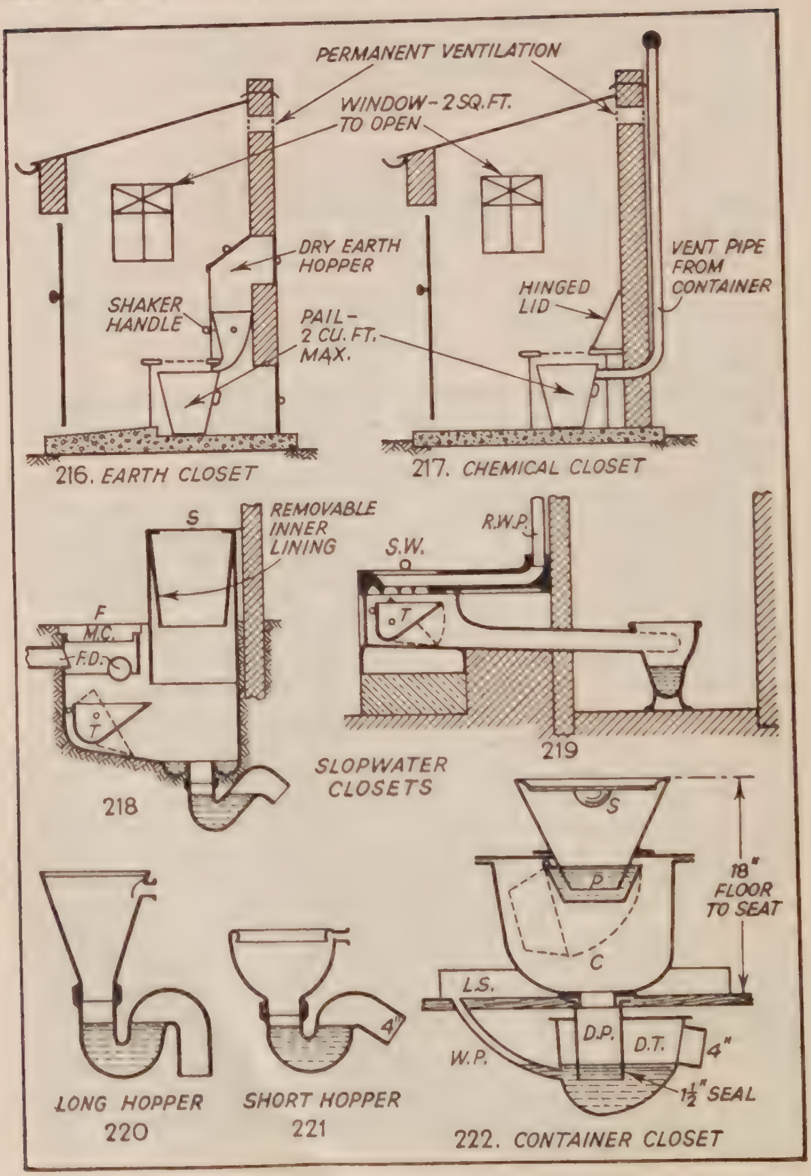
straight into the liquid, causing unpleasant splashing; when the lid is replaced the anti-splash plate is submerged into the disinfectant. The raising and lowering of the lid also moves an agitator or paddle which helps the chemical to disintegrate the faeces and toilet paper.

The capacity of the tank installed will normally be of such a size as to last an average household for several weeks without emptying and when this is necessary an outlet valve at the bottom is opened and the liquid and disintegrated faeces and toilet paper is allowed to pass through a 4-inch drain pipe to a soakaway well away from the dwelling and at least 100 feet from a well or spring used for drinking purposes. The chemical used for the tank model is usually a solid in the form of easily dissolved flakes instead of the liquid form.

The Water Carriage System. The fittings used in conjunction with the water carriage system include water-closets, flushing cisterns, lavatory basins, baths, sinks and urinals.

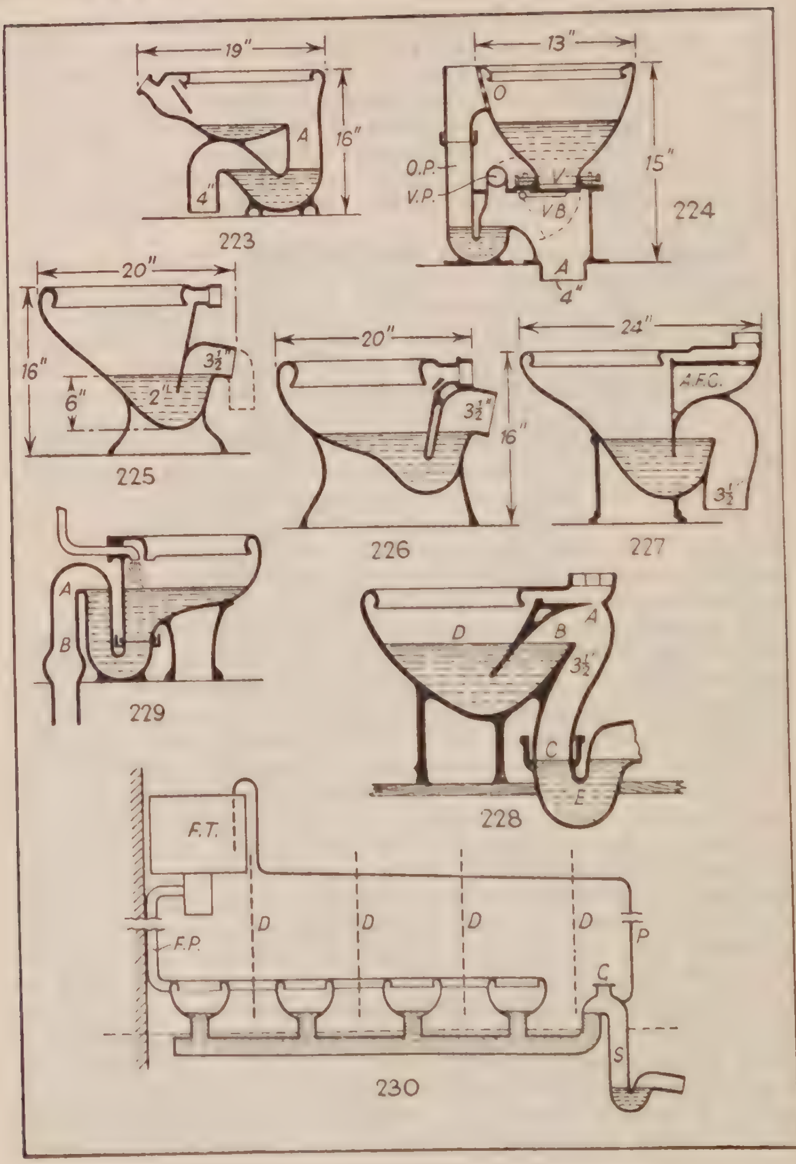
To be quite efficient all sanitary fittings should be of simple construction, as self-cleansing as possible, made of non-absorbent and incorrodible materials, and readily connected to waste pipes. All parts should be made readily accessible, and the fittings, as a general rule, should be left uncased, since casings or enclosures are very apt to become receptacles for dust and dirt.

Slopwater Closets. Slopwater closets are occasionally found in old buildings where there is not an ample supply of clean water. Fig. 218 shows an objectionable type, in which S is the seat, F the floor of the closet, and F.D. is a flushing drain, fed by the waste from a sink and by rainwater pipes. The flushing drain in these models usually has a very irregular discharge, so that there is seldom water available for flushing at the right time and the cleaning action is therefore ineffective. In Figs. 218 and 219 a tipper, T, stores up the waste water until there is enough to give a good flush at intervals, but there is still no guarantee that the water will be there when needed. The tipper is so hung that it overbalances and discharges its contents when full and regains its original position when emptied. In Fig. 218, a movable cover, M.C., is provided to give access to the tipper. The introduction of the tipper greatly increases the area liable to be fouled. Fig. 219 shows a type in which there is a proper closet pan with a water seal, flushed at the top by a spiral flush from a tipper placed above ground level; this is a much less objectionable type, but it is still far from sanitary, and a good type of earth-closet or chemical closet is much to be preferred.


PERMANENT VENTILATION
WINDOW - 2 SQ. FT. TO OPEN
DRY EARTH HOPPER
SHAKER HANDLE
PAIL - 2 CU. FT. MAX.
HINGED LID
VENT PIPE FROM CONTAINER
216. EARTH CLOSET
217. CHEMICAL CLOSET
S
REMOVABLE INNER LINING
F
M.C.
F.D.
T
R.W.P.
S.W.
T
219
218
SLOPWATER CLOSETS
S
P
C
18" FLOOR TO SEAT
L.S.
D.P.
D.T.
4"
W.P.
1½" SEAL
4"
LONG HOPPER
220
SHORT HOPPER
221
222. CONTAINER CLOSET

The Planning and Arrangement of Water Closets. The position and treatment of water closets and other sanitary fittings in the design of a building are matters of great importance. Wherever possible, all fittings should be placed against external walls, to ensure short branches to the waste or soil pipes. In flatted dwellings, hotels and buildings of several floors, all fittings of similar nature, if at all possible, should be arranged over one another on the various floors to simplify the plumbing.

Principles of Design for a First-class W.C. There are certain conditions that should be fulfilled in order to obtain a really sanitary closet. They include the following: (1) at least one wall of the apartment should be an external wall of the building; (2) there should be a good window, made to open for light and ventilation and so placed as to give plenty of light around the apparatus. The area should be at least 2 square feet and if the whole of this area is made openable so much the better; (3) a non-absorbent floor and walls, or, if this is impossible owing to cost, a tiled dado around the sides and back of the apparatus; in a public water-closet it is better that the walls should be of white glazed bricks or tiles, and the floor of tiles or granolithic, but in a private house this would generally be objected to on the ground of appearance; (4) a pedestal apparatus; (5) a trap forming part of the apparatus, or, if a separate trap, close to the apparatus and above the floor; (6) the pan and trap to be of incorrodible and white glazed ware, for preference the pan and trap made in one piece and of the same material; (7) the whole of the apparatus to be simple in design, with no movable working parts to get out of order, and to be easily accessible; (8) the pan should have a reasonable water area of adequate depth, especially where most of the droppings will fall, and should be easily accessible; (9) a siphonic water waste-preventing cistern over the back of the pan, it being placed there to obviate the loss of flushing power caused by bends; and (10) the full force of the flush should be directed on the contents of the trap and not wasted by being diverted to accessory parts. If such accessory parts be thought desirable, as in the case of some of the "siphonic" closets, a larger cistern should be used. The flush, in its passage to the trap, should thoroughly cleanse the pan. There should be no hidden inaccessible parts to a sanitary fitting no matter what the purpose of the fitting may be. Numerous examples of such objectionable items might be given, some practically obsolete, others doomed to become so. Such are the "Container" closet, the "D" trap, the "tip up" lavatory basin, basins and baths with


19"
16"
A
4"
223
13"
O
15"
O.P.
V.P.
V
VB
224
A
4"
20"
16"
6"
3½"
2"
225
20"
3½"
16"
226
24"
A.F.C.
3½"
227
A
B
229
D
B
A
3½"
C
E
228
F.T.
D
D
D
D
P
F.P.
C
S
230

overflow pipes entered only through a few small holes pierced in the material of the fitting, and so on.

Bad Types of W.C. Pan. In dealing with closet apparatus, it will be well to divide them into two sections, those which are objectionable, and those which are allowable or desirable.

Figs. 220 and 221 show two of the oldest forms of pan, known as the "long hopper" and "short hopper" respectively. The inlet in either type may have a flushing rim, as shown in Fig. 221, or merely a spreader, as in Fig. 220. Both types are to be condemned where found, because there is no water in the pan into which discharges may fall and the pan is very liable to be fouled.

Another very insanitary apparatus is the "pan" or "container" closet shown in Fig. 222. It has a conical basin of glazed earthenware, fixed over a cast-iron container, C, the outlet of the basin being closed by a hinged copper pan, P, holding water. When a handle in the seat was pulled the pan fell to the position shown by dotted lines, throwing the contents into the container, which became very foul. The water was admitted to the basin behind a spreader, S. The sketch shows the outlet of the container joined to a D trap, D.T., by the dip pipe, D.P., there being a lead safe or tray, L.S., on the floor, the waste pipe, W.P., of which communicates with the trap.

The "Washout" W.C. Pan. The next sketch, Fig. 223, shows a section through a "washout" closet. It is less objectionable than the "container" type, but is far from satisfactory. The pan is so constructed that there is a shallow basin of water directly below the seat, the water being of insufficient depth to cover deposits, resulting in smell. If the water be made deeper, the force of the flush from the cistern is insufficient to wash out the solids and change the contents of the basin. Further, the washing out of the basin throws solid matters against the side at A, leaving them to decompose until possibly washed out by the next flush, while the water merely falls into the trap without force. This type of pan should be condemned wherever found.

The Valve Closet. Fig. 224 shows a type of pan which has been much discredited, known as the valve closet. It is rather complicated, and in the old forms had many objectionable features. In the most modern forms, however, it can be classed as a sanitary fitting. The chief advantages claimed for it are (1) that it is almost noiseless in action, (2) the discharges fall into a fairly deep body of water, and (3) if the house is unoccupied for a long time there is great protection given by the depth of water against evaporation.

Even if the water above the valve is evaporated there is still some protection left by the valve fitting up tightly against the outlet and, further, there is still the trap with its water seal below the point A.

In London the valve closet is doomed by the regulations of the Metropolitan Water Board, which provide that all valve closets shall be flushed by water waste-preventing cisterns, which will negative the noiseless action.

The valve, V, is held up by leverage, and opens downwards on pulling up the handle in the seat. It allows the contents to pass through the valve box, V.B., into the trap below. It is possible that the valve may by accident become set fast, and an overflow pipe has therefore to be provided. The overflow openings are shown at O, and it will be seen that they communicate with the overflow pipe, O.P., which is open at the top for convenience of access. The overflow pipe is isolated from the valve box by a trap, and the valve box is provided with a ventilating pipe, V.P., carried to the outside of the building. The pan is of glazed earthenware, and the valve box and overflow pipe should be of cast iron, glass enamelled inside. Valve closets are usually cased in with a wooden seat and "riser" right across the apartment. In some of the later forms of valve closet, there is a vitreous-enamelled valve box, an accessible overflow pipe and the working parts are made so compact that the whole can be enclosed in a glazed earthenware casing or "pedestal", but the fitting still has too many working parts and is too complicated to be considered a good type.

The "Wash-down." One of the best forms of closet at the present time is that known as the "wash-down", one type of which is shown in Fig. 225. It will be seen that it is based on the hopper type, but that the outlet of the pan is sealed by water having a reasonable surface area. The back is made nearly vertical, and in some varieties of this type, quite vertical, to guard against fouling. There is a good seal to the trap, and a proper flushing rim is provided around the top of the pan. This is the type recommended in B.S. 1213 and students desiring more detailed dimensions, as recommended in the B.S.S., should obtain it from H.M.S.O. or borrow it from a library.

In some types of wash-down pan the trap is separate, and in such case the joint between it and the pan should be below water level, so as readily to indicate any defect in the joint, though this type carries with it the disadvantages of a slight roughness at the joint in the entrance to the trap, while the trap itself is often of a different material, rather spoiling the clean, uniform

appearance of the interior of the closet pan. The great advantage of the separate trap is that outlets can swivel in any direction in a half-circle for use in W.C. apartments in awkward positions or at odd angles to the outside soil pipe.

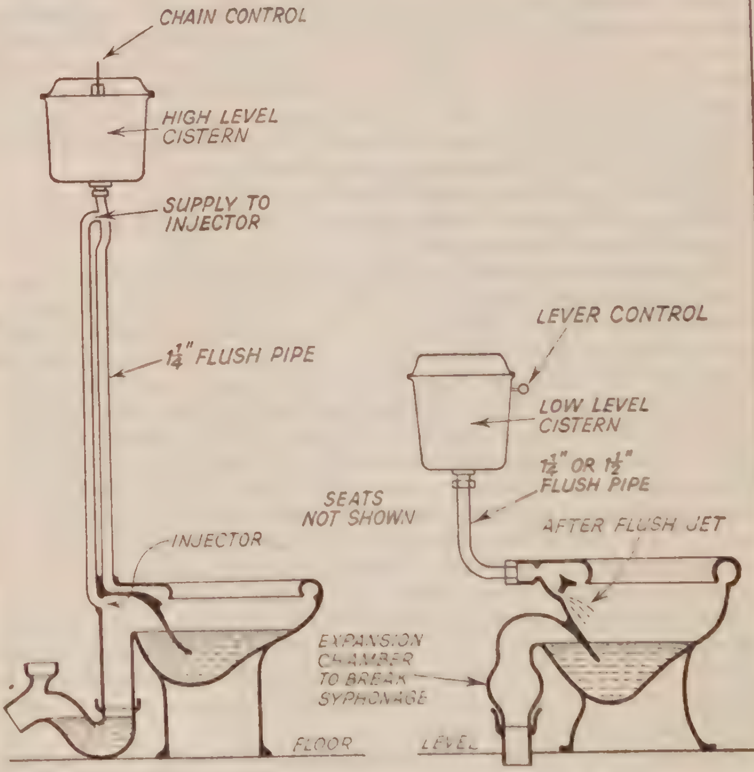
A recently introduced wash-down W.C. pan, known as the "pivot" closet, is designed with three-quarters of the trap made in one piece with the pan, but finishes with the spigot of the outlet vertically upwards just below the water level on the outlet side. The remainder of the outlet arm to complete trap can be supplied to form either a "P" or "S" type of trap and to swivel in any direction through approximately 180° as in the older forms of loose trap closet without any of its disadvantages.

A wash-down closet should have a good seal, not less than 2 inches, as it is rather liable to become unsealed if a bucket of slops be thrown into the pan.

Fig. 226 shows a second variety of this type of closet, a "wash-down" with large water area. With this type fouling of the pan is much less likely. The larger area of water is obtained partly by making the front more concave, and partly by increasing the depth of the seal. In Fig. 227 a third variety of wash-down apparatus is illustrated, differing from the two previous examples in the addition of an after-flush chamber, A.F.C., between the top of the trap and the underside of the flushing arm of the pan. When the pan is flushed, water enters this chamber and fills it, while the bulk of the water from the cistern passes on to flush the pan. The outlet of the after-flush chamber is small, and the water comes from it more slowly, in consequence, to ensure there being sufficient water left in the trap at the end of the flush.

The dimensions of wash-down pans are specified in B.S.S. 1213, which specifies (among other requirements) that the water surface shall be not less than 6 inches from back to front and $4\frac{1}{2}$ inches from side to side and that the back plate shall have an angle of from 90° to $107\frac{1}{2}$° to the horizontal.

Siphonic W.C. Pans. We come next to closets of what are known as the "siphonic type, of which there are two principal varieties, (1) those with two traps, and (2) those with one only. A good example of the former is shown in Fig. 228. When the chain is pulled most of the water flows around the flushing rim and so into the pan, but a small amount passes through the small aperture at A, in the form of a jet; as the pipe between A and C is enclosed, the air previously in it is compressed, forcing down the level of B and C and raising the level of water in the pan at D, which is further raised by the water from the flushing rim. As



INJECTOR TYPE SYPHONIC W.C. WITH 2 TRAPS

231

SINGLE TRAP SYPHONIC W.C.

232

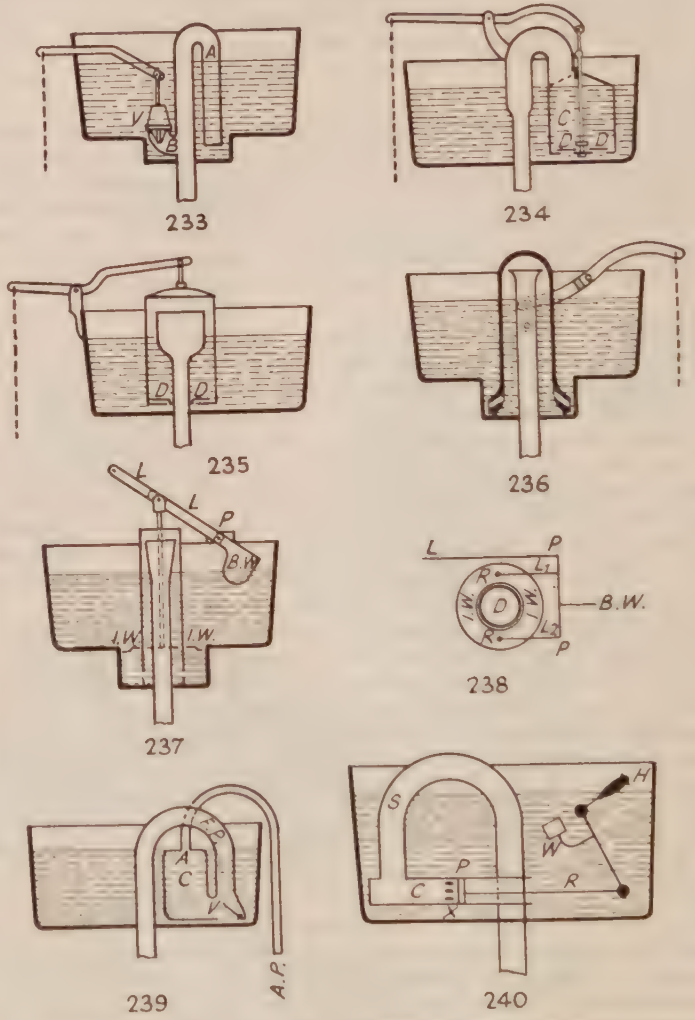
soon as the water level in the trap at C is depressed to the level of the bend at E, the compressed air escapes and the pressure in the pipe AC becomes normal. The heaped-up water in the pan now rapidly overflows into the outlet pipe and fills it completely, with the result that solids are removed from the pan by suction.

This apparatus is simple in character and quite efficient in action. The only objections to it are that the trap and its outlet rather prevent thorough cleaning of the floor behind the apparatus, and that part of the water that used to start the siphonic action—plays no direct part in the flushing of the pan. Another form of two-trap siphonic pan is shown in Fig. 231– this time with an injector tube from the top of the flush pipe to provide the starting jet.

Single-trap Siphonic W.C. Pans. A good example of the siphonic closet with a single trap is shown in Fig. 229. It will be seen that it has an exceptionally deep seal and large water area. The siphonic action is set up by rapidly raising the water level in the basin, and so overbalancing the other column of water, which fills the arm A.B., full bore. This arm has an enlargement of its section just below B, to which the ventilating pipe is fixed, obviating a check to the siphonic action at B, owing to the sudden compression of the air in that arm of the siphon. It will be seen that the soil pipe is still trapped if the basin is removed. Another example with low level tank is shown in Fig. 232.

Trough Closets and Latrines. Before leaving the description of the various types of water-closet, reference must be made to trough closets and latrines, such as are used in factories and some types of school. The oldest form is merely a semicircular trough, covered by a continuous seat with a series of holes in it, trapped at one end, and flushed out at intervals by means of an automatic flushing tank. Such a fitting is very liable to fouling, difficult to keep clean, and is quite lacking in privacy. Another type is in the form of an oval pipe running from end to end, with short oval branches passing up under the holes in the seat. This is better but still not good.

Even in the roughest of communities all closets should be separate to ensure reasonable privacy. Fig. 230 shows, diagrammatically, a good arrangement for such cases, in the form of a siphonic latrine. There are separate pans divided by divisions or partitions, D, and communicating with a longitudinal pipe, the end of which is raised to provide a body of water in each pan. A siphon, S, is fitted at the end of the range of pans, with an access



EXAMPLES OF W.W.P. CISTERNS IN DIAGRAM FORM.
(COVERS ARE OMITTED FOR SIMPLICITY)

cover, C, at the top of the bend. Each pan has a flushing rim, and the flushing pipe has a branch to each. An automatic flushing tank, F.T., provides the flush at frequent intervals and, after flushing, the siphonage is checked by a small pipe, P, which lets air into the siphon as soon as the water level in the flushing tank drops below the end of the pipe, shown by dotted lines inside the tank. The flushing tank would, of course, be higher than shown in the sketch, which is broken to save space.

The best arrangement, of course, is to have a separate pan, trap and flushing cistern to each compartment, but naturally extra expense is involved. The Ministry of Education insists on this in new schools.

W.C. Cisterns. We may next consider the means of flushing closets. The usual method is by means of a cistern, at a height of a few feet above the apparatus, with a capacity of two gallons. In some places a larger volume is permitted by the water authorities, but in very few. For a siphonic closet a three-gallon flush should be used wherever possible. Cisterns have ball-valve inlets similar to those in storage cisterns.

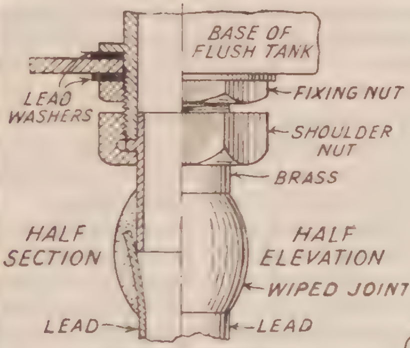
Flushing cisterns have in some respects been standardised by B.S.S. 1125. They may be of $\frac{3}{16}$ inch cast iron, $\frac{1}{2}$ inch glazed ware, pressed steel of 16 B.G., $\frac{3}{4}$ inch wood lined with 4 lb. lead or 24 S.W.G. copper, or $\frac{1}{2}$ inch asbestos-filled or fibre-filled bituminous composition.

The old type of cistern was operated by means of valves, the pulling of the handle raising the valve and letting the water out. To empty the cistern, it was necessary to hold the handle till the water had all gone. Some types had one valve, others two, but cisterns of this kind have now been superseded by others of siphonic action, of the "pull and let go" type, termed siphonic water-waste preventers (or "W.W.Ps" for short). They are so called because they limit the amount of water which can be used at each flush. There are very many forms of such cistern, but a few examples will indicate the principles underlying the construction of practically all of them. They differ only in the method of setting up the siphonic action. In the following sketches, which are diagrammatic, the ball valves and overflow pipes are omitted for the sake of clearness. It should be mentioned, in this connection, that the overflow (or "warning" pipe which is a better name for it) should be a size bigger than the inlet, since the water coming in is under pressure, whilst the overflow has none and would certainly not be able to deal with the surplus water in the event of a defective ball valve, unless of larger size. The water-supply pipe is usually

$\frac{1}{2}$ inch, while the overflow is made $\frac{3}{4}$ inch. The example shown in Fig. 233, though siphonic in action, has a valve, and in consequence is objected to by most water undertakings. On pulling the handle the valve, V, is raised and allows water to rush through the branch, B. The effect of this is to lessen the pressure of the atmosphere on the small surface of water, A, with the result that the water rises over the bend and sets the siphon in action, the water continuing to flow until it falls below the level of the open inlet of the pipe.

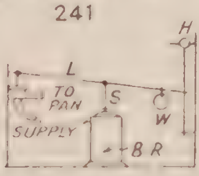
In Fig. 234 the pulling of the handle lifts a body of water into the bend and so starts the siphon. The end of the pipe in the cistern terminates in a cylinder, C, closed at the top and open at the bottom so that water can rise into it when the cistern fills. Through this cylinder passes a vertical spindle which lifts a circular disc, D.D., on the handle being pulled. It is by this disc that the water is lifted, the disc fitting quite loosely in the cylinder. Another variety of this type is shown in Fig. 235, in which the cylinder or dome is movable. It is raised by pulling the handle, and lifts a body of water on a loose disc, D.D., as before, into the mouth of the vertical pipe. This removes the atmospheric pressure in the dome and starts the siphonage. Another way in which the same principle is applied is shown in Fig. 240. In this case the pulling of the handle pushes a loosely fitting piston, P, along the open end of the pipe and forces a body of water over the bend. The examples in Figs. 234 and 235 show that siphonage can be started by lifting a body of water vertically, that in Fig. 240 by a horizontal force, and that in the next illustration, Fig. 237, by a vertical downward force, Fig. 238 being an outline plan of the cistern. Around the dome, which in this case is fixed, is an iron disc or washer, I.W., which on being forced down forces the water up under the dome and into the mouth of the flushing pipe. There are three levers all joined together in one casting and pivoted on the line P.P. At the end of lever L is the handle, and at the ends of the levers L_1 and L_2 are vertical rods, R.R., connected to the iron washer. As the handle is pulled down, the rods go down too, forcing down the washer; the equilibrium of the apparatus is restored by a balance weight, B.W.

In cisterns of the type shown in Fig. 236 the lever is forked so as to grip the two opposite sides of the heavy cast-iron dome, or bell, the short connecting piece, shown in dotted lines, ensuring the vertical rise of the latter. On releasing the handle, the weight of the dome forces the water up and over into the flushing pipe, thus setting up siphonage.



SCREW UNION
241

RUBBER CONE
(TO CONNECT FLUSH PIPE TO PAN)
242



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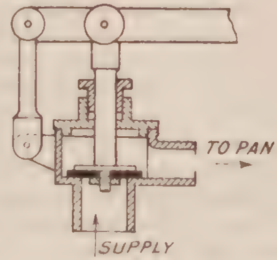

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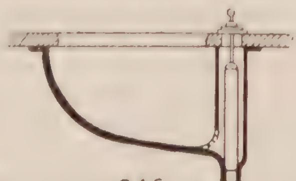

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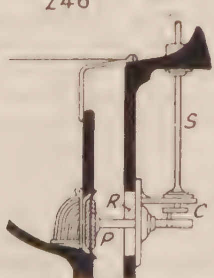

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Pneumatically Operated W.C. Tank. Fig. 239 shows a cistern operated pneumatically instead of by a handle. A loosely hinged valve, V, enables the water to rise into the open end of the flush pipe, F.P., and into the chamber, C. The small pipe A.P. is an air pipe passing down to a point about 2 feet above the seat, where it terminates in a small circular leather bellows actuated by a push button like that of an electric bell. On pushing the button, sufficient force of air is exerted at A to drive the water out of the chamber and over the bend of the flushing pipe.

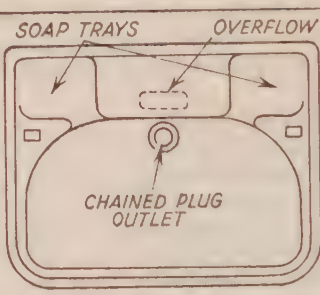
Low-level Cisterns. Figs. 239 and 240 show mechanisms suitable for use in "low-level" cisterns for placing at the back of the pan and just above seat level. In Fig. 240, a piston, P, actuated by a pivoted handle, H, and a piston rod, R, works in a cylinder, C; the cylinder communicates with the siphon, S, which is fixed at a slight cant so that its long outlet leg may be clear of the cylinder. In the cylinder are some holes at X, by which water enters the cylinder from the cistern after a flush, these being placed immediately in front of the piston when this is in its normal position of rest. When a flush is required a movement of the handle, H, causes the piston to move to the left, covering up the holes and driving water up the short leg of the siphon. The piston travels a small distance past the short leg of the siphon, so that the whole body of water in the cistern, entering the cylinder at its open end, can pass over the siphon, to be discharged by the long outlet leg to a connection at the back of the pan. As long as the flush continues the rush of water along the cylinder will keep the piston at the far end of its stroke, even if the handle is released; when the flush has stopped the counterpoise weight W will cause the mechanism to return to the position shown in Fig. 240. Low-level cisterns are very popular to-day, partly perhaps because they are so accessible for adjustment or repair. They have not quite the head of water of the high-level tank, but this is partly made good by the fact that a more direct flush can be obtained, with only one easy bend, and partly by using a flush-pipe of rather larger diameter—say $1\frac{1}{2}$ inches instead of $1\frac{1}{4}$ inches; it is also an advantage to have a tank capacity of $2\frac{1}{2}$ or 3 gallons instead of the normal 2 gallons. Most water companies and boards permit only 2 gallons when water is paid for by "rate", and make a surcharge of from 5s. to 10s. a year for each W.C. using a bigger cistern. The apartment needs to be a trifle longer from back to front than is normally necessary, owing to the space taken by the cistern. Low-level cisterns are suitable for either wash-down or siphonic pans.

Time of Discharge and Refill. A two-gallon water-waste preventer should discharge in about five or six seconds, and refill in from a half to one minute, the longer of these periods being allowed if it is desired to avoid noise.

Flushing Valve Closets. The method of flushing a valve closet is necessarily different from that applicable to closets with a free outlet. Fig. 243 shows the arrangement in outline. The outside line shows an iron frame. It carries a handle, H, to which a lever, L, is connected, the lever controlling the water inlet to the pan. On pulling up the handle the water is turned on, and as the lever, L, falls by reason of the weight, W, it is gradually shut off. It would be instantly shut off but for the bellows regulator, B.R. This consists of a cylinder containing a small leather bellows connected to a spindle, S, the bellows having a valve at the bottom. The spindle passes through the bellows and collapses it as the handle is raised, and the descent of the spindle can be retarded to any extent by means of a small tap fixed near the top of the cylinder.

Other forms of regulator are used, but that described is the most usual. Some forms of inlet valve do not require regulators, but they are usually complicated in construction and liable to get out of order. Fig. 244 shows the construction of the usual form of water inlet for a valve closet. It will be seen that it is opened by the raising of the lever and closed as the lever goes down again. If a valve closet is to be flushed by means of a water-waste preventing cistern, the pull of the cistern can be coupled up to the levers of the valve apparatus.

W.C. Flushing Valves. Water-closet flushing valves of excellent design and workmanship, for flushing ordinary wash-down and siphonic types of pan, are on the market and the arrangement of a W.C. apartment so provided is shown in Fig. 253. These make the use of a W.W.P. cistern unnecessary. They are very neat and efficient, and can be adjusted and sealed by a water company so as to pass 2 gallons (or other prearranged amount) each time a button or lever is pressed. They do not make much headway, except with property owners providing their own water supply, owing to the fact that most water companies are rightly jealous of the purity of their supplies and consequently ban any water-valve or other fitment which might result in the least fear of "back-siphonage" from the fitting into the mains. The makers claim that a chamber provided in the valve makes such back-siphonage quite impossible, but they have not—to date—been able to persuade the Metropolitan Water Board and others to



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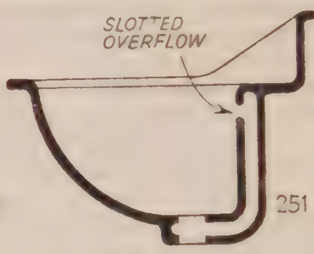
PLAN



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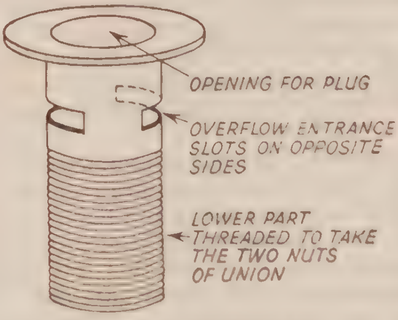
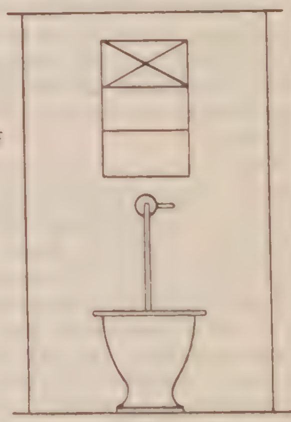
SECTION



252 – OUTLET "LINER" PORTION OF SCREW UNION FOR BASIN



DIAGRAMMATIC SECTION OF W.C. FITTED WITH W.W.P. VALVE

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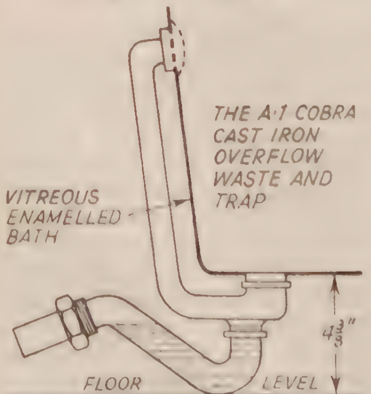

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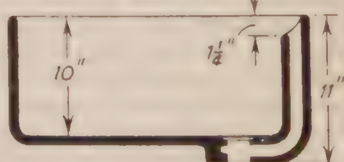

"BELFAST" PATTERN SINK WITH PLUG AND WEIR OVERFLOW

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relax the regulation prohibiting the use of such valves by their consumers.

Lavatory Basins. Lavatory basins may be made of earthenware, fireclay, stoneware or vitreous china. B.S.S. 1188 specifies a size of 25 inches by 18 inches for general use, or 22 inches by 16 inches for use where space is limited, while the requirements of a good basin are indicated in Code of Practice 305 (1952) (Sanitary Appliances).

The most important point in their design is that the overflow shall be readily accessible for cleaning. Fig. 245 shows a common form of overflow which is quite inaccessible, while Fig. 246 shows one which is nearly as bad. In the latter, the waste and overflow are combined, in a small chamber behind the basin, in the form of a vertical hollow tube, the lower end of which acts as a plug. On pulling up the knob at the top, the water can escape, and in case the basin is filled too full, the water flows over the open top of the tube and away through the outlet. This form of overflow and plug can be readily made accessible by putting it in a recess at the back of the basin instead of in an enclosed chamber. It is true that, as shown in Fig. 246, the top plate can be unscrewed and the tube lifted out for cleaning, but this seldom gets done, it being a case of "out of sight, out of mind". If in an open recess, the tube can hang on a hook and be readily lifted off for cleaning.

Slot Overflows. The most popular form of overflow to-day has a rectangular slot opening into the overflow tube instead of small perforations. It is shown at Figs 250, 251. This form is recommended by the Code of Practice mentioned above, but the form shown in Fig. 248 is much more accessible for cleansing. The outlet for the slotted overflow type of wash-basin and for the more usual weir type is contrived with a flanged "liner" or tube (generally of chromium-plated brass), long enough to reach from the recess or rebate in the ceramic basin to the shoulder nut of the screw below which holds the trap close under the basin with a watertight joint. The detail is the same as Fig. 252 except that the flanged liner (or tube) has two rectangular openings on opposite sides making it possible for the overflow channel in the ceramic basin to link up with whichever of the rectangular openings happens to be opposite even if the plumber, in using his spanners to tighten the nut, moves the liner out of square.

The overflow channel terminates in a ring groove round the outlet so that the overflow water can always find its way out of the trap and waste-pipe below.

Weir Overflows. A good form of overflow is that known as a weir, two varieties of which are shown in section in Fig. 247. In both these cases the overflow bends round to join the outlet of the basin. A much better form is shown in Fig. 248, the overflow being larger, and leading straight down to the mouth of the trap below the fitting. It need hardly be said that the overflow is not the full width of the basin, but merely consists of a recessed chamber. The entrance to the overflow is often guarded by a brass or nickel-plated grating, hinged to the basin.

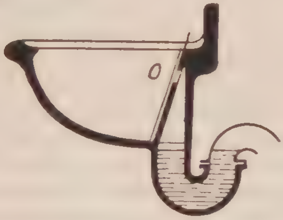
An excellent but more expensive form of waste and overflow is shown in Fig. 249. Both overflow and outlet are guarded by gratings. Behind the outlet opening is a plug, capable of being moved backwards and forwards by a lever handle at the top of the spindle, S. When the waste outlet is opened by a turn of the handle, the plug, through the agency of a crank at C, passes back into a recess, R, leaving both outlet and overflow fully open. It will be seen, too, that the overflow passes vertically down to the trap and is quite accessible. Its cost is likely to prevent its general adoption.

"Gate" Type Waste and Overflow. Quite a different kind of waste and overflow is shown in Fig. 256 of the type known as a gate waste. Across a recess in the back of the basin is a plate of metal or vulcanite, sliding in grooves and shown by a thick line in the sketch. An overflow opening is cut in it as at O, and the lifting of the plate allows the water to run away. On removing the plate the whole of the overflow passage is accessible. In the particular example shown, the trap is partly formed in the basin itself to obviate the existence of even the short length of pipe that would otherwise occur above the trap and be liable to become fouled.

"Tip-up" Basins. The arrangement of the "tip-up" type of lavatory basin is shown by a line diagram in Fig. 257. The chamber below the basin, and the underside of the latter, are apt to become coated with dirty soap suds and, while this can be readily removed by lifting the basin out, a fitting which requires no such attention is obviously preferable, and it must be considered an undesirable type.

Fixing of Basins. Lavatory basins should be fixed on brackets or cantilevers, so that the space below them is uninterrupted and accessible, and the wall behind them should be faced with non-absorbent material, such as tiling.

An alternative fixing—a little more expensive—is to support the basin on a pedestal of the same material as the basin. This



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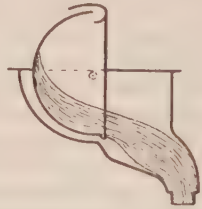

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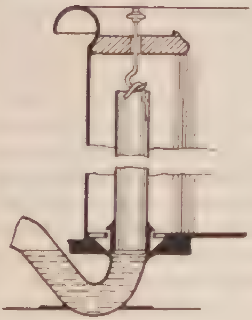

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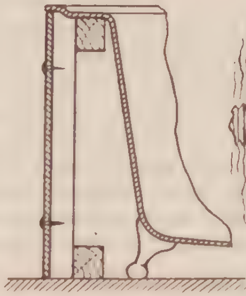

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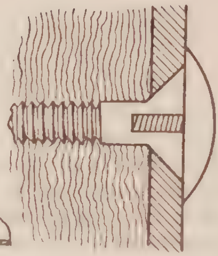

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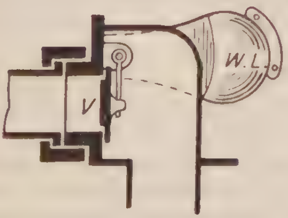

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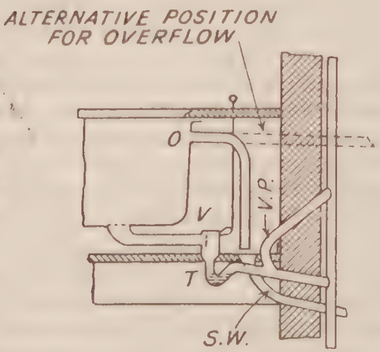

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gives a neater appearance, but an opening has to be left at the back of the pedestal at the top for the plumber to gain access to the water-supply and waste-pipe joints and provide a catchment for dust which is quite inaccessible for cleaning. It also adds to the difficulties of fitting the floor covering. Still another method is to support the basin on a metal frame with adjustable legs resting on the floor. Only two legs are necessary and this method leaves better access to the pipe by the plumber and to the floor by the housemaid, while the floor covering can be slipped under the base of the legs when the adjusting screws are removed and the set screws can then be screwed up to give proper support afterwards.

Basins in Bedrooms. A prominent feature of late years has been the tendency to fit lavatory basins in bedrooms. From a purely sanitary point of view it is not desirable to have any opening to the drains in a bedroom, but there is no question as to the convenience and saving of labour which result, and the improved form of fittings and traps now available make the objection perhaps more fanciful than real, provided the fittings and workmanship are of the best. Great care, however, must be taken to choose a basin with a sanitary type of overflow and the trap must be of anti-siphonic or "resealing" type unless the trap is provided with an anti-siphonage pipe which is difficult to mask and makes the plumbing more obtrusive; these will be described later in this chapter.

Lavatory Ranges. For schools, offices and other buildings where a number of basins is required, it is often an advantage to arrange the basins in a double row in the centre of the floor in the form of an island. A dwarf wall is built up to the level of the range of basins to provide support. The plumbing can then either be left open in the ordinary way or the wall can be made wide enough to enclose a plumbing cavity in its centre with a neat enamelled steel short cover along the top for inspection. This arrangement leaves the walls of the apartment free for the accommodation of urinal stalls, W.C.'s, etc.

Baths. The general principles of the design of baths are similar to those for lavatory basins. There should be a good-sized waste outlet and an accessible overflow. While lavatory basins are now almost invariably of glazed fireclay or vitreous china, there is a much larger selection of materials in the case of baths. They have been made of tinned copper, cast-iron either paint-enamelled, stove-enamelled, or porcelain-enamelled, of white glazed fireclay or earthenware, or of marble.

The obsolete copper bath took very little heat out of the water, but

required to be carried on cradling in order to be strong enough to stand the weight of the water and of the individual. Further, it was often found that the floor of the bath got uneven and prevented the entire emptying of the water. Such a bath must also be enclosed. Cast-iron baths were often used in small houses on the score of economy, being finished with stoved enamel paint. Such baths are very difficult to keep clean, and the extra cost of porcelain enamel, i.e. enamel which has been vitrified, is amply justified, the inside of the bath being then non-absorbent and highly glazed. Porcelain or fireclay baths are satisfactory but open to the objection of cost and are slow in warming up, as the material absorbs so much heat from the water.

Marble baths look well, but they are costly to construct, and it is certainly difficult to get a really hot bath in one unless the user is prepared to wait while the marble warms up.

There is a British Standard Specification (B.S. 1189) for porcelain enamelled cast-iron baths, which is now the most commonly used form.

Overflow and Waste for Baths. A common form of overflow to a bath is one guarded by a readily removable circular grating, but this is not as good as a type which is immediately accessible. The form of waste and overflow shown in Fig. 249 is also applied to baths. Fig. 258 shows the application of the tube waste and overflow combined, the tube being attached to a hook. Such tubes can be of metal or vulcanite and should stand in a recess at the end of the bath, as in the case of lavatory basins. A form of waste outlet sometimes adopted is that shown in Fig. 262, which shows, diagrammatically, a valve outlet, V, controlled by a weighted lever. A chain or rod connects the lever with the top of the bath casing where this method is adopted. In some places the water authorities will not allow a bath overflow to be joined up to the waste pipe, but require it to be treated as a warning pipe. Fig. 262 shows the arrangement of the pipes which results in such a case, assuming a valve outlet to be used. The sketch is perhaps self-explanatory, but it will be seen that the overflow pipe is discharged over the mouth of the waste pipe of the lead safe under the bath. The valve leads into a trap, T, which is provided with a ventilating pipe, V.P. Alternatively the lead safe can be omitted and the overflow will then be taken straight through the external wall to discharge over a garden bed or yard, as shown by the dotted lines.

One of the problems encountered in dealing with the outlets of baths is that of fixing the trap and its joints in such a way that

they are above floor level where they will be accessible, and it is quite usual to find them below floor level. A skilfully designed overflow, plug outlet and trap is shown in Fig. 254. It is the "Cobra" combination fitting made by the A.I. combination of iron-founding firms to fit the baths of any member firm.

The Cobra is in coated cast-iron or glass-enamelled iron in two pieces which screw together where indicated. The ends of the overflow and outlet are finished with screwed nipples. These nipples are then fixed from inside the bath with the threaded overflow plate and the outlet flange plate, while a screw-union with tailpiece at the outlet end of trap enables the lead or other form of waste pipe to be connected.

Enclosed, Free-standing and Panelled Baths. At one time, baths were usually enclosed in a mahogany or other wood casing. There was seldom an hermetical seal at the top and the interior often got damp and musty. There was generally a hinged access door to the plumbing and the housemaid often used the interior as a store cupboard for wet housecloths and other cleaning kit, making matters worse. Then came a reversion to the free-standing bath with a roll top on dwarf feet, to avoid the wood casing. This type would be perfectly hygienic in a large bathroom, but in the modern small house where the bathroom may not be much bigger than 6 feet × 5 feet, the space under and around the bath is very inaccessible and difficult to keep clean, especially if the floor is of wood and the linoleum or other floor covering is laid by the occupier with a rather bad fit against the walls and around the short feet of the bath. Splashes and dust pass in between the walls and the roll top of the bath to accumulate in the angles and behind the (possibly) curled up edges of the floor covering to defy the housewife, trying to keep the apartment clean. As a result, most baths to-day are parallel-sided, fitting closely with an hermetical seal up against two or even three bathroom walls, with the remaining side or sides panelled, as shown in Fig 259. The panels may be of glazed panelled plastic, of decorated Poiliti or other asbestos-cement sheeting, of Vitreolite, of marble, or of vitreous china or glazed fireclay. Tiles are sometimes used, but this entails either inaccessible plumbing or a hinged door at the plumbing end, undoing most of the advantages of the panelled type. The panels should be held in place by four or six good-sized screws on a wood framework, the slotted heads of the screws being hidden by screwed, domed caps as shown in Fig. 260, these being only friction tight and inserted or removed by the fingertips dipped in powdered resin. The edges of the panels should be seated in

rubber strip or red lead putty, to keep the interior dry and free from mustiness.

Different Types of Sink. There are several varieties of sink, including the scullery sink, butler's pantry sink, slop-sink, and housemaid's sink.

Scullery sinks are of two kinds, shallow and deep. The shallow sink has usually a grating outlet and really serves only the purpose of a safe, to catch spills, splashes, etc., from the bowls or basins which will be used there and to act as an outlet via which the water emptied out of the bowls may reach the outside gulley and the drains. Having an open grating as outlet it requires no overflow. Scullery sinks are often used as washing-up sinks, and in such case require plug outlets, and consequently overflows, which, as in the case of other fittings, should be accessible. If intended as washing-up sinks, they should be about 10 inches deep. This form, sometimes called the "Belfast" pattern, is shown at Fig. 255. Some are fitted with a removable hardwood or aluminium draining-board. Some also are made in two compartments, one for washing and the other for rinsing, in which case the overflow is usually put in the partition between the two sinks. A desirable feature in such a sink is a high back or skirting, of the same material as the sink and usually made in one piece with it. The height from floor to top of sink is best made about 2 feet 10 inches.

They are usually made of fireclay, which is easily cleaned, but are now often made of stainless steel, or of an alloy of copper and nickel, the draining-board being generally combined with the sink. Plastic sinks with combined draining-boards are also on the market, but though their appearance is pleasing and the surface smooth and easily cleansed, they have not yet been on trial for a long enough period to guarantee the surface against the hard usage to which a scullery or kitchen sink is usually subjected. Lead, copper or wood are unsuitable for the greasy work of a scullery sink, and are open to other objections, but cast iron or pressed steel are satisfactory materials, if porcelain enamelled. Fireclay sinks are standardised by B.S.S. 1206 and metal sinks by B.S. 1244.

In large establishments separate sinks are often provided for the dressing and cleaning of vegetables. They can be very similar to the double sink just described but usually have standing (or tube) wastes and overflows, with a removable perforated copper shield round to prevent the passage of grit, potato peelings, etc., into the waste pipe.

A very usual fitting in Scottish houses is a washtub made and fitted independently of the sink or as a combination fitting discharging into a common waste pipe. Of late years, these tub and sink sets have become popular all over Great Britain, especially in housing schemes.

They are usually constructed of cane-coloured stoneware or of white-glazed stoneware and the plug and overflow arrangements are similar. The water supply can be independent or a swivel form of "mixer" tap may be used to serve both tub and sink, provided the water company's rules do not preclude this form of tap. They are not likely to object providing the cold supply comes from a service tank, but if it comes direct from the main, they usually object owing to the risk that water from the consumer's hot-water cylinder may make its way into the company's mains.

Butler's or Pantry Sinks. Butler's pantry sinks should not be of glazed fireclay owing to the more delicate nature of the articles washed in them—china, glass, etc. Pressed metal sinks are now the most popular. Formerly they were either of hardwood, such as teak, or of wood lined with copper, tinned copper or white-metal. In the former case they were made up of boards grooved and tongued together, and jointed with red and white lead putty, the whole being bolted together with galvanised iron bolts. All the internal angles were rounded to facilitate cleansing, and if such sinks were well looked after they were suitable for the purpose.

If the sink is metal lined, the outer sink of wood should have its internal angles rounded or splayed. Copper is serviceable as a lining but is difficult to keep clean in appearance. Tinned copper or white metal are much better, but lead is unsuitable, owing to its surface becoming very uneven on exposure to hot and cold water in turn.

Drip Sinks. Small drip sinks are often provided under draw-off taps on landings and in housemaids' closets. They are really more in the nature of lead safes than sinks, and are formed usually on the floor by laying down a wood border of half-round section, and lining the whole with sheet-lead. A grating outlet should be provided, leading to an untrapped outlet passing through an external wall like a cistern overflow.

Slop-sinks or Slop Hoppers. In a relatively small building slop-sinks are rarely found, a pedestal closet with a dished slab top, or slop top, admirably serving the purpose. In very large houses, hospitals, hotels and similar buildings, however, they should be put. They are made of porcelain-enamelled cast iron or of glazed earthenware, in shape somewhat like a W.C. pan, with a flushing

rim, and a water waste-preventing cistern over. One sometimes finds them with a hinged grating over, and hot- and cold-water taps to facilitate the washing of bedroom utensils. This arrangement is not good, owing to the possibility of the cold-water tap being used for filling water bottles.

Not only is it objectionable to fill bottles from a tap over a foul fitting, but the taps are apt to be used to hang clothes on that have been used for washing bedroom utensils. A much better way is to arrange a housemaid's sink and a slop-sink side by side, the taps over the former and the flushing cistern over the latter. The outlet of the housemaid's sink is in the form of a grating and its waste pipe discharges into the side of the slop-sink. The outlet is treated like that from a W.C.

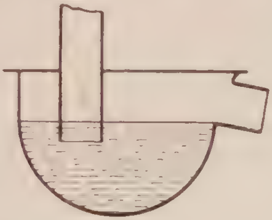
Urinals. In a dwelling-house one does not often find a separate urinal. A pedestal closet with a lift-up seat fulfils the purpose adequately. A few words on the design of urinals will not, however, be out of place. At one time the idea was to get as little fouling surface as possible, using the old-fashioned upright or lip basins, with waste pipes leading from them. Though such a basin may be perfectly flushed, the surrounding wall and floor is liable to fouling and is unflushed. It is better, therefore, to give a much larger fouling surface, recognise that practically every part of the urinal is liable to be fouled, and provide for the adequate flushing of such larger surface. The whole of the work around a urinal should be of non-absorbent materials, such as tiled wall and floor glazed fireclay urinal stalls, etc. About the best type of urinal is that made up of stalls which are curved on plan, have upright backs, and shaped bases discharging into a glazed channel in front, covered by a readily removable brass or galvanised grating. An automatic flushing cistern should be used, its capacity being dependent on the number of stalls, a usual allowance being one gallon per stall. The water reaches the stalls through perforated, or sparge, pipes.

Urinettes. These are similar to small wash-down W.C. pans, sometimes found in ranges in factories employing many women. There are usually inset teak pads instead of the usual hinged seat and the flushing is usually automatic, like a range of men's urinals, with one gallon of water allowed per pan. There might be a light swing door to each compartment, closed with a spring. The only advantage over a range of W.C. pans is that the compartments can be smaller, three urinettes fitting into the space occupied by two W.C.'s, and the space from back to front also can be reduced a little —about 2 feet × 3 feet 6 inches on plan.

They have been found unsatisfactory for use in public conveniences and public places generally, as they tend to be misused owing to lack of knowledge of their function. The case is different in a factory, as it is customary in this case to employ a woman welfare officer who can explain their use to newcomers on the staff.

Bidets. The bidet is a wash-basin used in the toilet of the private parts and used chiefly by women. It is to be found in the bathrooms of well-appointed private houses of the larger type, as well as in some hotels, public or semi-public institutions of various kinds. In appearance it is a cross between a wash-basin with hot and cold taps, plug waste and overflow and a W.C. pan, "fiddle" shaped on plan, with flushing rim, pedestal support and about 16 inches in height, but without a seat. As the user has to sit on the cold fireclay or vitreous china of the flushing rim, the hot and cold water controls (usually on a separate pedestal or pillar alongside the bidet) deliver into a mixing chamber leading into the flushing rim, warming it as the basin fills. An extra lever on the control pillar is generally provided to operate a warm vertical jet from the floor of the basin. This jet and the outlet are placed about 6 inches from the rear of the fitment, where it will be most likely to play upon the appropriate parts of the user. Needless to say, the lever controlling the jet should not be operated until the user is in position, seated on the bidet with legs astride. In the past, local authorities have been in much doubt as to whether the bidet should be connected to the soil pipe with the W.C.'s and urinals or to the waste pipe with the baths and basins. All by-laws (if they mention it at all) require the bidet to be connected to the waste pipe to-day (unless "one-pipe" plumbing is in vogue) and there is no doubt that that is the correct procedure on sanitary grounds.

Trapping of Outlets. The outlets of all ordinary sanitary fittings should be "trapped". There are a large number of kinds of trap, good, bad and indifferent, and it will be well first to deal with the essentials of a satisfactory trap. The object of a trap is to prevent the pollution of air. Thus, in the case of a lavatory basin, there would be a length of waste pipe which would get more or less coated with dirty soapy water, the pipe therefore becoming a foul pipe. The air in the room being warmer than that outside the house, the colder air would pass through the pipe to the room, and be contaminated. This can be prevented by the use of a trap, which should be put as near to the fitting as possible. In the case of a W.C. the necessity for the trap is, of course, far greater, since the W.C. is either directly connected to the drain or is connected



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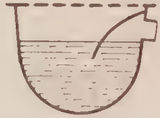

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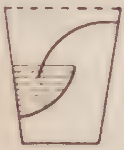

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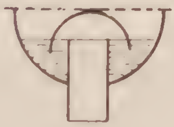

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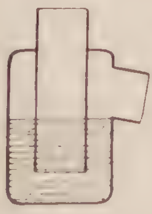

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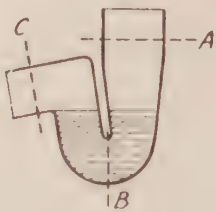

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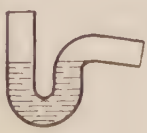

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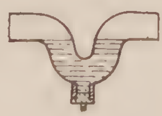

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to a soil-pipe by a short branch, the former being directly connected to the drain and not disconnected as in the case of a lavatory, bath or sink. The connection of soil-pipes with the drain will be discussed in detail later in this chapter, but it may be said at once that the reasons for connecting the base of the soil-pipe direct to the drain are mainly (i) the need to get the soil, sanitary paper and flushing water from W.C.'s away from the house as quickly as possible, the velocity down the soil-pipe being a useful aid to a self-cleansing velocity in the drain provided not hindered by a trap at the base; and (ii) the tendency which a second trap at this point would cause, or to help in causing, siphonage or failure in the W.C. traps leading into the soil-pipe higher up.

Qualities of a Good Trap. A satisfactory type of trap is one that is self-cleansing, simple in form, devoid of angles, corners, or cavities, holds only a small quantity of water with a good depth of seal, made of incorrodible materials, and easily connected to fittings and to pipes.

Bad Types of Trap. We shall deal first with types which should be condemned. Fig. 263 shows a D trap and Fig. 264 a "lip" trap; neither of these is self-cleansing, both have inaccessible parts and hold too much water. Figs. 265 and 266 show other forms of lip trap, which are little better. A trap of another form, yet very similar in principle, is that known as the "bell" trap. It is illustrated by Fig. 267 and was at one time largely used for sinks. The dotted line shows the grating outlet of the sink, to which is attached a bell or dome, the latter dipping into a channel of water, circular on plan. It was very liable to get choked, when it was at once unsealed by lifting up the grating with the help of a fork. To overcome this objection, the "inverted bell" trap was introduced. From Fig. 268 it will be seen that in form it is open to as much condemnation as the ordinary bell trap, though it could not be so readily unsealed. The inverted bell was, of course, kept in position by light metal stays, connecting it to the casing of the trap.

A trap of entirely different form is the bottle trap shown in Fig. 269. It usually had a good seal, but is open to serious objections unless its interior is accessible; this was not the case in early models, but an accessible bottle trap is now made, either in polished aluminium, chromium-plated brass or gun-metal, or stainless steel, and is less ugly than the ordinary types of trap and consequently more suitable for the modern type of unenclosed basin. An example of an anti-siphonic bottle trap is illustrated in Fig. 282 and will be described later in this chapter. Mechanical traps were at one time very popular, but they are unnecessarily complicated

and possess no advantages. An example of such a trap, known as a ball trap, is shown in Fig. 270. The ball can be of vulcanite or rubber, and is intended to supplement the small water seal shown. All the traps already described, except the accessible bottle trap, must be regarded as bad forms.

The "Anti-D" Trap. The simplest form of trap is merely a bent pipe. It obviates angles, cavities, or any inaccessible parts, and gives a self-cleansing type. Fig. 271 shows a section of an "Anti-D" trap which fulfils most of the essentials of a satisfactory trap. The funnel-shaped inlet is not bound to be present in a trap of this type, but it is certainly a desirable feature. A cross-section at A is circular, at B oval, and at C a square with the corners rounded. The object of the last-mentioned feature is the prevention of siphonage of the water seal and, while this is effected, it is in almost all cases wise to use other means also of guarding against siphonage. This peculiar section of the outlet makes the "Anti-D" trap a little more difficult to connect to pipes than if it were cylindrical. Interest in "Anti-D" traps has been revived in recent years for use in "one-pipe" plumbing systems (described at the end of this chapter). For this purpose, the "Anti-D" trap has been made in brass with a deep (3-inch) seal and a brass screw-union to connect it to the fitting and waste pipe.

The "S" or "Siphon" Trap. One of the best types of trap is the "S", "Q" or "P" trap, so called because of the similarity of its shape to these letters when its outlet is vertical, sloping or horizontal respectively and shown in Figs. 272, 273 and 274.

It is of circular section throughout, simple and self-cleansing, with a good seal while holding a comparatively small body of water. In the smaller sizes, 2-inch diameter and less, it is provided with a screw-cleaning eye at the lowest point, as shown in Fig. 273, which is a section of an S trap. A form which is midway between the S and the ½-S, shown in Fig. 274, is known as a Q or ¾-S trap. With the smaller sizes of all these traps a screw-cleaning eye is provided. The question as to which of these traps is used for any particular case is largely dependent on the available room. One other form, also quite a sanitary trap, is that known as a "running" trap (Fig. 275).

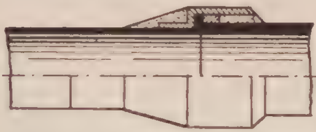
Materials for Traps. The best materials for traps are drawn lead, copper and copper alloy. They are easily connected to fittings and pipes, and are incorrodible. If iron is used, the trap should be glass-enamelled inside. B.S. 504 specifies the composition and weight of drawn lead traps and their dimensions and

water seal, while other non-ferrous traps are dealt with in B.S. 1184.

W.C. Joints. The joints around the various fittings next call for attention. In the case of a W.C. there is the joint between the flushing pipe and the apparatus; also that between the trap and the soil pipe. The flushing pipe is joined to the cistern by means of a screw-union as in Fig. 241. The tail-piece of the union is soldered on to the flush pipe (if of lead) by a plumber's wiped joint. The lower end is usually attached to the socket of the flushing rim by a rubber or plastic cone, shown in Fig. 242. The cone is first pushed up the pipe out of the way and the end of the flush pipe is placed into the socket of the flushing arm and a joint is made with putty of red and white lead, the cone being then pulled down from its temporary resting place on the lead flush pipe until the expanded end fits tightly over the fireclay socket and the smaller end over the lead flush pipe so as to completely cover the joint. Some joints are made with rubber rings compressed by screw collars, so as tightly to pack the space between the lead and earthenware. Another method is to use special collars of lead, hinged together in two pieces and secured by a small bolt. The collar connects the pipe to the flushing arm and is packed inside with red and white lead. One sometimes finds the rubber cone joint just mentioned bound with two or three strands of copper wire around the flushing rim socket and the base of the flush pipe, but this is not necessary if the rubber cone is a proper fit, and the securing twist of wire and the interstices of the coils provide lodgment for dirt and germs. In low-cost housing schemes, the flush pipe is often of telescopic pattern, in two or three sections, so as to be adjustable for different cistern positions. The material is then thin galvanised or vitreous enamelled steel and the sections are slightly varied so that the upper length can make a close fit inside the middle length and the middle length inside the bottom section. The sections are coated with a thick paste of red and white lead putty before being fitted into one another and adjusted, any surplus paste being cleaned off after the fixing is complete.

The top section is provided with a flange with the shoulder-nut of the screw-union engaged, so that no separate flanged tailpiece is needed. The bottom section can then be fitted to the flushing rim socket in the same way as the lead flush pipe, with red and white lead putty and a rubber cone joint.

The joint between the trapped pan and soil pipe depends on the material of the latter. If it is of iron a cement or bitumen joint is all that is needed, but a branch socket with a wide faucet for



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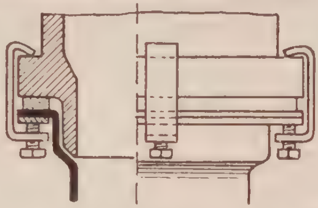

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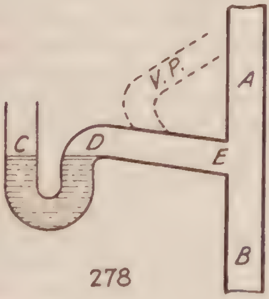

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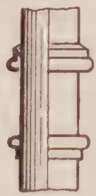

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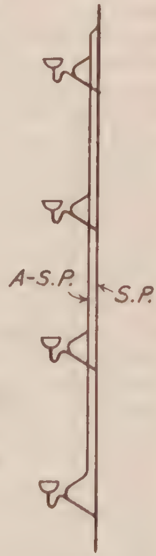

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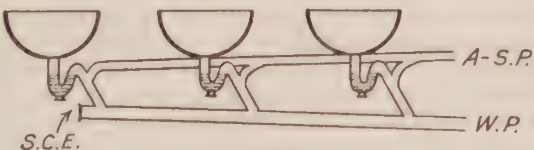

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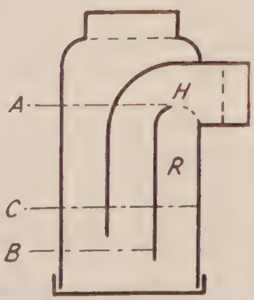

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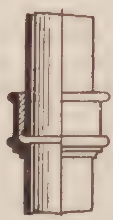

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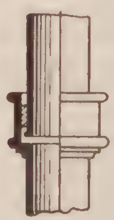

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cement should be specified if cement is to be used, as the normal socket for a caulked lead joint is too narrow for a first-class Portland Cement joint. If the soil pipe is of lead, or if a lead branch soil-pipe is to be used, a variety of means may be adopted. One sometimes sees the lead dressed out to form a shallow socket which fits over the pan outlet, the space being filled in with red and white lead putty, but this is a poor method and should be condemned. A better plan is to use a copper, brass or gunmetal ferrule, as shown in Fig. 276, soldered to a lead pipe with a sloping shoulder wiped joint, or bronze welded to a copper pipe and connected to the pan with a cement or bitumen joint. As this joint and the one between the W.W.P. cistern and the flushing rim of the pan are exposed in the apartment to spillage of urine or slops, every care should be taken to obtain an easily cleansed, stream-lined joint, for which reason Fig. 276 should be preferred to Fig. 277.

This joint (i.e. No. 277) is a quick and strong joint for the same conditions and materials as Fig. 276. It is shown half in section and half in elevation.

It is made up as follows. Between the lead pipe (tafted out with the hardwood cone and tafting tool to the shape shown) is a flat rubber ring, and outside the lead a flat brass ring. Screw clamps, as shown, are used to bind the whole together.

Still another method of getting over the difficulty of ensuring a strong watertight joint between the pan and the lead soil-pipe branch is found in the Metallo-Ceramic joint. The outgo of the pan is coated before firing, with a liquid composition containing a solder adhesive metal in solution. On removing from the kiln a thin film of metal is left on the outgo, which will hold the solder. A short length of lead pipe is then soldered on at the factory, and to this the plumber on the job makes his conventional wiped joint.

Plumbing for Basins and Baths. The joint between lavatory basins, baths and sinks and their respective traps, if of lead, are made by means of screw-unions and wiped joints, both before described.

Anti-Siphonage Arrangements. In almost all cases a trap below a fitting is liable to lose its seal. It may do so in either of three ways: (1) By evaporation, (2) by siphonage, and (3) by momentum. To guard against evaporation, a deep seal should be provided. To guard against the second and third cases, the trap should be ventilated.

The reasons for this will be seen from Fig. 278. For example, if the fitting charged the trap full bore when emptying, the volume of water acting on C would overbalance the atmospheric

resistance at D, and the water would either all pass through CDE, emptying the trap, or would cause a partial vacuum at D. It is, however, well known that nature does not allow a vacuum, therefore the trap would be emptied. This may be obviated by putting a ventilating pipe, V.P., near the outgo of the trap, in order to supply air and preserve the seal.

Again, if there were two or three fittings, one over the other, discharging into the same waste pipe, the lower traps would be liable to siphonage from another cause. A discharge down the pipe AB tends momentarily to compress the air in front of it and the effect of this would be to cause a slight excess of pressure at D, momentarily overcoming the normal atmospheric pressure at C and raising the level of the water at that point. Almost immediately after, however, the discharge has passed the end E of the pipe DE, suction is caused behind the falling liquid, tending momentarily to lessen the pressure on the surface of the water at D, allowing the atmospheric pressure on C to raise the water level at D and lower it at C. This is called siphonage by momentum, and if the discharge is fairly vigorous and fills the pipe, the contents of the trap are almost certain to be forced out. This increasing and decreasing of the pressure on the surfaces of the water forming the seal is very similar to the bouncing of an elastic material. The ventilating pipe near the outgo of the trap provides an escape for the increased pressure in the first instance and supplies the air to meet the diminished pressure in the second case. A ventilating pipe to a trap is generally known as an anti-siphonage pipe.

The form of the connection of the vent pipe should be particularly noted from Fig. 281. It will be seen that the pipe is joined by a bend, pointing in the direction of the flow through the trap, which is the only satisfactory method, as it obviates the fouling of the entrance to the pipe. If it is connected vertically, or in any other way than that shown, the entrance is very liable to become stopped up. Though not generally provided for in the provinces, the by-laws of the London County Council prohibit any other method in the Metropolis than that shown in the illustration.

Should a fitting be quite separate from any others, its trap may be ventilated, except in the case of a closet or housemaid's sink, by carrying the vent pipe through the nearest external wall, enlarging its outer end, and fitting it with a circular grating flush with the wall, well away from windows, being then described as a "puff pipe".

Each trap should be separately ventilated, but where the fittings

are arranged in tiers, or in ranges, the anti-siphonage pipes of the traps may be branched into a main anti-siphonage pipe. This method is shown diagrammatically in Fig. 280, which shows a method of dealing with the wastes of a range of three lavatory basins. Each basin is shown separately trapped, and discharging into a main waste pipe, W.P., and each trap is ventilated into a main anti-siphonage pipe, A-S.P. At the end of the waste pipe a screw-cleaning eye would be provided, S.C.E., and a similar cleaning eye would be put at the bottom of each trap. Sometimes ranges of lavatory basins are dealt with differently, the separate waste pipes not being trapped but discharging over and into an open channel trapped at the end, the lower ends of the waste pipes being furnished with a bend pointing along the channel.

Anti-siphonage Pipes for Water Closets. Fig. 281 shows the arrangement of a tier of closets with each trap ventilated into a main anti-siphonage pipe, which is finally turned into the soil-pipe at least 3 feet above the highest fitting. An alternative is to carry the main anti-siphonage pipe well above the roof instead of connecting it to the soil-pipe. In the sketch, the anti-siphonage and soil-pipes are shown one behind the other for the sake of clearness, but the two pipes would be parallel on the outside face of the wall. Anti-siphonage pipes can be of either lead, copper or iron. It should be noted, in passing, that it is not necessary for the anti-siphonage pipe to flow in the same direction as the waste or soil pipes as in Figs. 280 and 281. If it suits the lay-out better, or a neater appearance is obtained thereby, the anti-siphonage pipe can discharge to the left with the waste or soil-pipe delivering to the right (or vice versa) so that the anti-siphonage pipe reaches the eaves by an independent route.

For ordinary closet work, branch vent pipes of 2 inches in diameter are sufficient, discharging into a main anti-siphonage pipe a size larger.

Special Anti-siphonage Fitments. In order to reduce the number of joints to be made at each floor when a tier of soil fittings has to be connected to iron, soil and anti-siphonage pipes respectively, special castings are sometimes used, incorporating the anti-siphonage branch, and providing one socket only to take the closet outlet, two sockets upwards (to take the spigots of the main vent and soil-pipes from upper floors) and two spigots downwards, ready to be jointed to two similar plain lengths of main vent and soil-pipe passing down to the lower floors and to the drains.

The "Spruce-Thrower" Soil Unit. In one fitment of this type,

shown in Fig. 286, (the "Spruce-Thrower Soil Unit") the anti-siphonage branch is taken from the soil branch of the unit straight towards the main soil-pipe without staggering right or left, and by-passes it in the form of a circular ring-duct immediately below the socket, this ring-duct for air, opening out into the main anti-siphonage pipe which is bolted on as a prefabricated unit alongside. In this fitment, bosses are cast on in suitable places and drilled and tapped, so that, in areas where "one-pipe" plumbing is permissible, bath, basin and sink wastes can be connected directly to the "general-purpose" soil-pipe.

The anti-siphonage branch for lavatory basins, baths and sink traps can be a size smaller than the diameter of the trap concerned, the main anti-siphonage pipe, if for waste pipes only, being of the same diameter as the trap. For the range of basins in Fig. 280 fair sizes would be as follows: traps and branch wastes $1\frac{1}{2}$ inches, waste pipe 2 inches, branch vent pipes $1\frac{1}{4}$ inch, and anti-siphonage pipe $1\frac{1}{2}$ inch. If the main vent pipe is very long, its diameter should be slightly increased.

Traps and Fittings not needing Anti-siphonage Pipes. The trap of a single closet on a ground floor, with none above it, is not usually ventilated, but it becomes necessary if another is at any time allowed to discharge into the same soil pipe at a higher level.

A scullery sink on a ground floor need not have its trap ventilated, for the reason that a flat-bottomed vessel does not charge its trap full bore all the time it is emptying, and also, that in the case of such a fitting on a ground floor, the waste pipe would be of short length, and disconnected, so that the air in it could never exert any appreciable excess over the normal pressure of the atmosphere.

Anti-siphonic Traps. An alternative to the use of anti-siphonage pipes for waste fittings is to use anti-siphonic traps or "re-sealing" traps. Fig. 282 illustrates one, known as the "Sure-seal". It is an improved form of bottle-trap, with complete accessibility by means of a screw-cap base. Normally water stands in it at level A. When water is discharged from the basin and flows through the outlet full-bore, causing suction, siphoning will begin. When, however, water falls to level B air will pass from the room to the outlet and bring its pressure up to the normal. Meanwhile the water in the "reservoir" R has been unable to escape through the very small holes H at its top, and, as soon as equilibrium of pressure is restored, this water will fall and the water in all the trap will reach a common level C, the outlet being sealed once more.

Waste Pipes. We may next consider the kinds of waste pipe, the materials used for them, their joints, fixing and the methods of dealing with their top and bottom ends. They should normally be outside the building; but where it is permissible to use the "one-pipe" system of drainage, to be described later, it is advantageous to put the vertical soil and ventilation pipes in a vertical shaft constructed as part of the building, with suitable means of access. The waste pipes comprise rainwater pipes, carrying the rain water from the roofs, soil-pipes, taking wastes from closets and housemaids' sinks, and pipes taking the wastes from baths, lavatories and sinks.

Material for R.W. and Waste Pipes. Rainwater pipes are usually of cast iron, while waste and soil-pipes may be of lead, copper or cast iron.

The branch wastes from baths, basins and sinks are generally of lead, though drawn copper is a most satisfactory alternative, being very durable. Copper pipes may be chromium or nickel plated, if desired, and are especially suitable for the waste pipes from basins in bedrooms. A cheap, but not very sightly, alternative material for waste pipes is galvanised wrought iron.

Pipes are also made of asbestos cement, with bends, branches, shoes and swan-necks of the same material. They form a cheap and fairly satisfactory rainwater pipe, but they are rather brittle and may be broken by a knock, as, for example, by a ladder. If used as soil, waste, or ventilating pipes they are coated with bituminous composition. They are specified in British Standard Specifications 569 and 582.

"Drawn Lead" Pipes. Lead pipes should be of what is known as drawn lead, that is to say, seamless, and they may usefully be specified as to be to the Standard of B.S. 602. Before the introduction of drawn-lead pipes, the pipes were made up of sheet-lead with soldered seams, and such pipes are often found in old buildings; they are very apt to be found defective. Lead and copper have the advantage over iron in that they are incorrodible, obtainable in longer lengths (necessitating fewer joints), will give slightly, without damage, if there is settlement of the building, and the joints can be more perfectly made. The lead of soil-pipes should weigh not less than 8 lb. per square foot of surface.

Drawn Copper Tubes. Copper tubing should be "solid drawn" and for sanitation purposes is dealt with by B.S. 659.

Cast-iron Soil-pipes. Cast-iron soil, waste and ventilating pipes should be of medium or heavy section or they will not stand the caulking of the joints. The minimum weights allowed by B.S.

416 are: for pipes 3 in. in diameter, $30\frac{1}{2}$ lb. per 5 feet length; for $3\frac{1}{2}$ in. diameter. 36 lb.; and for 4 in. diameter, 40 lb.

Cast-iron rainwater pipes can be of lighter section, since they do not need caulked joints. They are specified in B.S.S. 460.

All cast-iron pipes should be protected against corrosion by the Angus Smith process or by galvanising.

The diameters of soil-pipes are usually fixed by local by-laws. The Model By-laws of the Ministry of Housing and Local Government prescribe a minimum diameter of 3 inches, as also do the by-laws of the London County Council. It is a great mistake to use a soil-pipe of so large a diameter that it does not properly get flushed throughout each time a water waste-preventer is discharged. Provided it is large enough for the work it has to do, the smaller it is the better, as it will be kept in a clean state; $3\frac{1}{2}$ inches is a sufficient diameter for a tier of three closets, but 4 inches would be necessary for a building of about six floors and $4\frac{1}{2}$ inches for higher buildings.

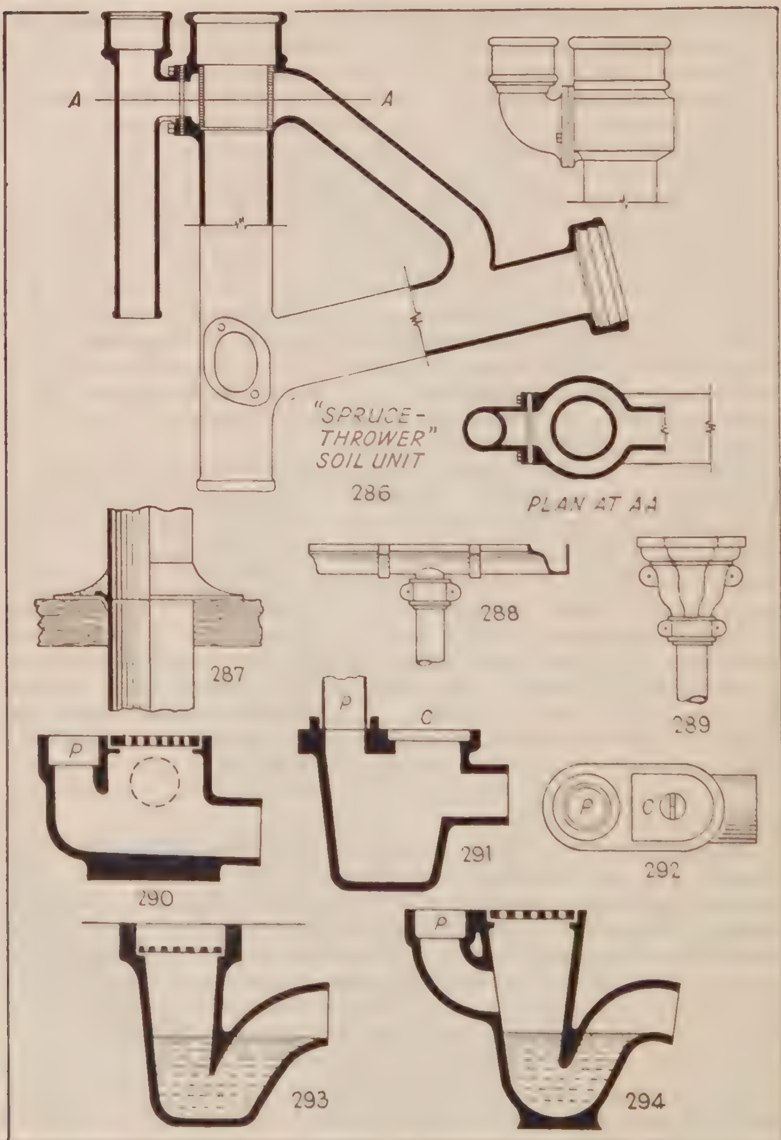
Plumber's "Wiped" Joint. Lead soil-pipes should be jointed with wiped soldered joints. Sometimes a fancy joint known as the astragal joint is found, but it is not strong enough for soil-pipe work. It is illustrated in Fig. 279. Occasionally in old work one comes across the joint shown in Fig. 283, known as the blown, or copper-bit, joint, but this is entirely unsuitable for a soil-pipe.

Copper soil-pipes usually have bronze welded joints, either formed in the pipes themselves or with the use of weldable fittings.

Caulked Lead Joints. Cast-iron soil-pipes should have caulked lead joints, as shown in Fig. 284. A few strands of tarred hemp are first rammed into the socket and the remaining space is then filled with molten lead, which is afterwards hammered or "caulked". Lead wool may be used instead of molten lead, if it is sufficiently soft to be easily caulked.

Jointing of R.W. Pipes. Cast-iron rainwater pipes should be jointed with red lead putty, but they are often found without any jointing material, the adjacent ends merely fitting one within the other. This has the advantage that, if the outlet becomes choked with fallen rust and leaves, it will overflow from a joint low down, instead of at the top, so that the area of wall made damp will be far less; on the other hand, if the pipes are jointed, the greater head of water standing in the pipes will be likely to force out the obstruction, so that jointing is to be preferred.

Asbestos-cement pipes, which are socketed and made in 6-feet lengths, are jointed with tarred gaskin, bituminous compound and finished with cement mortar.


A
A
"SPRUCE-
THROWER"
SOIL UNIT
286
PLAN AT AA
287
288
289
P
C
291
P
290
P
C
292
P
293
294

Waste and Overflow Pipes. In the case of lead waste pipes and overflow pipes, the weights of the pipes should be what are known as "middling", as opposed to the "strong" pipes used for water services. The following table is a guide to this.

Internal Diameter of Pipe	Minimum Weight per Yard of Length
1 inch	5 lb.
$1\frac{1}{4}$,,	7 ,,
$1\frac{1}{2}$,,	9 ,,
2 inches	10 ,,

Preferably the diameter should not be less than $1\frac{1}{4}$ inch, whilst $1\frac{1}{2}$ inch is highly desirable for bath wastes.

There is a point to be contended with in the case of waste pipes from baths, lavatories, and sinks, which does not occur in soil-pipes or rainwater pipes, due to the fact that water of varying temperatures, from hot to cold, passes through them. If of iron, they are often jointed with caulked lead, but lead is an unsuitable material as its coefficient of expansion is different from that of iron, the result being that the fluctuations of temperature cause the weakening of the joint. Portland cement or red lead are often used and are not open to the foregoing objection. Rust cement is also a good material, made up of cast-iron borings and sal ammoniac, the resulting cement having about the same coefficient of expansion as the iron pipe. If the cement is required to be quick-setting, sulphur may be substituted for the sal ammoniac.

Expansion Joints. Expansion joints are sometimes used, when non-rigid conditions are required. Rubber rings may be used in the sockets but they are objectionable on the ground that they perish. A better plan is to use a tightly packed band of greased hemp. Such a joint is shown in Fig. 285. It is difficult to form a satisfactory expansion joint in a lead pipe, but a form commonly found is made by enlarging the end of one pipe to form a socket, the end of the adjoining pipe being also enlarged, but merely at its extreme end. The two pipes are put together with a tightly fitting india-rubber ring between them, a collar being soldered round the upper pipe, with sufficient projection to prevent the rain getting into the joint. Wiped soldered joints are often used on main waste pipes. From the fact that the expansion and contraction is less appreciable, and can be better provided for in iron, it is

better to make main waste pipes of that material, provided they are properly protected against corrosion.

If the main pipe, either waste or soil, is of iron, and the branch pipe of lead, the joint is best made by means of a brass thimble or ferrule.

Inspection and Cleaning Eyes. In all main wastes or soil-pipe systems on an extensive scale, proper access caps or doors should be provided at principal bends and junctions, for the purpose of inspection and cleansing if necessary.

Fixing of Pipes. Iron rainwater pipes are fixed, usually, by means of lugs or ears, cast on the pipe at the side of the socket. In very large pipes, or ornamental ones, they must be fixed by means of iron straps gripping the pipe just below the sockets. Lead pipes may be fixed by means of tacks as already described, soldered to the pipe, or by means of cast straps. In the case of soil-pipes, if of iron, straps are used, the heavier sections of pipe not being provided with lugs or ears; if of lead, the usual method is by means of soldered tacks of sheet-lead, three being used to every 10 feet length. Sometimes a soil-pipe is fixed in a chase or groove formed in the wall, and in such case a common form of joint is the flange joint shown in Fig. 287. It will be seen that such a method not only provides a means of jointing, but, at the same time, of fixing, a washer of sheet-lead being placed around the joint where the pipe passes through a hole in a wooden block, and the joint completed by means of solder.

For bath, lavatory and sink wastes, the pipes are fixed by lugs, straps or tacks, according to the material and the size of pipe. Wherever iron pipes are to be painted, it is a good plan to fix them away from the wall so that they are accessible all round. This is easily accomplished by special iron collars made in two pieces, the back one having an arm to build into the wall. Another great advantage of this method is that in case of leakage the liability of dampness on the wall is reduced to a minimum. Iron soil, waste and ventilating pipes may be obtained with projecting ears, which tends to a neater fixing, while still providing the clearance behind the pipe for painting, making the use of distance pieces unnecessary.

Top and Bottom of Waste and R.W. Pipes. We may next consider the methods of dealing with the upper and lower ends of these pipes, on the supposition that the "one-pipe" system is not used.

In the case of rainwater pipes the pipe is either connected to a cast-iron or pressed-steel gutter, or terminates in what is known

as a hopper head. Fig. 288 shows a nozzle outlet of an eaves gutter, the nozzle fitting into and being jointed to an ordinary rain-water pipe. In the case of a parapet or similar gutter, a hole is formed in the wall, and lead dressed through, to discharge over a rainwater head or hopper head, which has an outlet jointed to the socket of the rainwater pipe. Such heads can be of either iron or lead, of varying shapes on plan, such as rectangular, half-octagonal, semicircular, etc. Fig. 289 shows one in the form of half an octagon.

Open End of Soil-pipe. The upper end of a soil-pipe should be carried up 3 feet above the head of any windows or skylights if they are within 15 feet laterally. It should have its end in as exposed a position as possible, and not be placed in an angle beside a chimney or any similar position, the object being to enable the wind to blow across the top of it and induce an up-draught. Again, if just against a chimney-pot, there would be a possibility of a down-draught conveying smell into the room served by the chimney. There should be no bends in this upper end of the pipe, if avoidable, so as not to check the up-draught, and the top of the pipe should be provided with a copper wire-ball grating to prevent obstruction by birds' nests.

The upper end of a main waste pipe serving baths, lavatories or sinks should be similarly treated, but, being of smaller diameter, a wire-ball grating is unnecessary, and the usual plan is to fix two wires at right angles across the top by means of solder.

Foot of R.W. Pipes. The method of dealing with the foot of a rainwater pipe will depend on the nature of the drainage system, the procedure differing according to whether or not there are separate drains for the rainwater. If the pipe discharges into a drain used exclusively for rainwater, two methods are available. One is to connect the rainwater pipe directly to the drain by means of a tapered bend, using a cement joint. One often finds, say, a 3-inch pipe jointed to a 4-inch stoneware bend, which gives a very poor job owing to the difficulty of making a satisfactory joint, but if a bend tapering from 3 to 4 inches diameter is used, a good job can be made. The other method is to use a rainwater "shoe" or "trapless gully" of iron or stoneware. A section of such a shoe is given in Fig. 290. The rainwater pipe is connected at P, but if it is required to connect a second pipe it can be readily done at the side, as shown by the dotted line.

The grating allows for the ventilation of the drain and also gives access to any accumulation of rust. Another method of dealing with the rust difficulty is to use a proper "rust pocket". Fig. 291

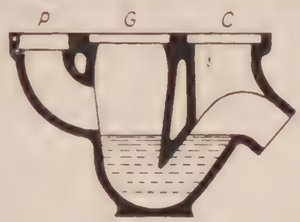
shows a section, and Fig. 292 a plan of such an item. It will be seen that a fairly deep receptacle or pocket is provided directly under the pipe, made accessible for the removal of the rust, which often falls in flakes, by means of a cover at C, fixed at ground level. Rust pockets should also be put at the foot of any iron pipes, other than soil pipes, used in connection with the ventilation of any drain.

Trapped Gullies. If there is only one set of drains, taking both foul wastes and rainwater, it becomes necessary to disconnect the rainwater pipes from the drains; if not disconnected, they will act as drain ventilators, and their upper ends are not in suitable positions for this purpose, even if the pipe be perfectly jointed. The usual method is to terminate the lower end of the rainwater pipe with a shoe, or spout in the form of a bent terminal section of pipe having a projection of about 1½ inches, and discharging over a gulley. A common form of gully is shown in Fig. 293. It will be seen that it is nothing more than a trap with its inlet at ground level. A well-designed gully should fulfil the following conditions: (1) It should be of self-cleansing form; (2) it should have a seal of not less than 2½ inches; (3) it should have a flat base to ensure its stability and permit of its being firmly set; (4) it should be set perfectly level and be securely jointed to the drain; (5) the grating should have good openings to deliver the water rapidly into the gully and yet be small enough to keep out leaves, etc.; and (6) the grating, if of iron, should be protected against corrosion, and should permit of ready removal for cleansing the gully, while having, normally, a watertight joint.

If to be used in a path, or in the middle of a yard, the upper surface of the grating must be flush with the top of the gully, but if under a rainwater pipe it is an advantage to have a deep top to the gully, to obviate splashing, the grating being 2 or 3 inches below the top, as shown in Fig. 293.

Another method of dealing with the foot of a rainwater pipe is to discharge the rainwater *into* a gully below the grating and above the water level, the rainwater pipe fitting into a socket as shown at P in Fig. 294, which shows what is known as Hellyer rainwater interceptor. It is merely a gully with a back inlet as well as the usual grating at the top. Additional inlets can be provided at the sides if desired.

Figs. 295 and 297 show, respectively, a section and plan of something a little more elaborate for the same purpose. One or more pipes can be connected to the gully, below the grating G, but above the water level as in the last case, but in this example a



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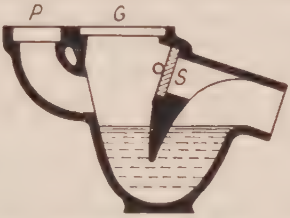

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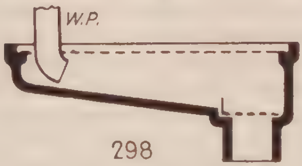

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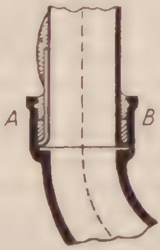

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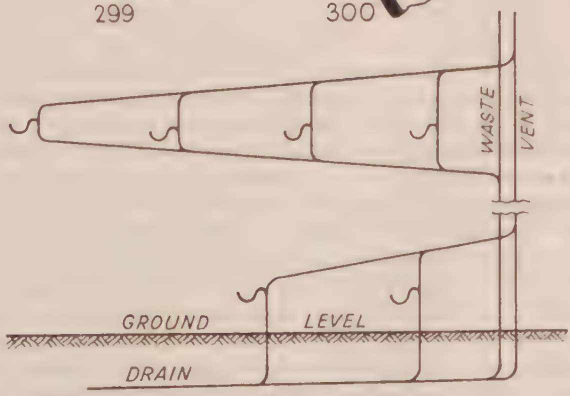

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means of access to the drain is provided in the form of a tightly fitting cover, C, at the outlet of the gully. This cover should, of course, have a secure, airtight joint. Another form of access gully is shown in Fig. 296, there being no access cover at ground level as in the previous case, a securely jointed stopper being provided at S instead.

An alternative method of dealing with a rainwater pipe, or any other pipe carrying only clean water, is to discharge it into a branch drain by a trapless gully, as shown in Fig. 290, and to disconnect this branch drain from the main drain by a trapped gully, similar to Fig. 294 except that the inlet will be horizontal. The branch drain has through ventilation between gully gratings and rainwater pipes and is known as an "air disconnected drain". Instead of leading into a back-entrance gully, such a drain may discharge into a convenient manhole via a "reverse-action intercepting trap" as shown at Fig. 338.

Use of R.W. Hopper for Waste Water. Waste pipes from baths or similar fittings are often taken through the wall and discharged there, over a rainwater hopper head such as that shown in Fig. 289. This practice is open to objection, as the dirty soapy water splashes round the mouth of the hopper head and remains there decomposing. This is apt to lead to a sickly smell, which frequently finds its way into the house. In some places this method is prohibited, and in any case it is very undesirable.

Waste pipes from such fittings should extend down to the ground and should also extend upwards above the roof, if they take waste from two or more fittings at different levels; if, however, a waste pipe takes the waste from only one fitting, or from two adjoining fittings on the ground floor, this latter requirement is unnecessary. The lower end of the pipe is not connected directly to a drain, but disconnected by means of a gully, which gives a first line of defence against drain air, the second line being the trap under the fitting.

Foot of Main Waste Pipe. It is better, however, not to discharge the waste immediately over an ordinary gully, in the same manner as a rainwater pipe, as the greasy and soapy water will splash over the gully top and collect there. A good method is to discharge the waste over a channel leading to a trapped gully grating at least 18 inches away. Fig. 298 shows such a channel, made of glazed stoneware. The dotted lines indicate gratings, the lower one being over the inlet to the gully, and the upper one being intended to prevent the obstruction of the channel by dead leaves, etc. Channels for this purpose should be of careful design, free from angles and corners.

Another method is to discharge the waste into a gully below the grating and above water level, as shown for rainwater in Figs. 295 to 297. This method of connecting waste-pipes to the drains is considered the most satisfactory to-day, owing to the fact that the grating cannot accumulate a coating of grease or soap curd and so cause an overflow of dirty waste or bath water over the surrounding ground—a very likely occurrence in autumn when leaves of trees are falling freely to complete the blockage. It uses slightly more pipe but there is a saving in labour with the brick on edge and rendered dishing to the gully top.

Grease Traps. A third method is to use a grease trap. Grease traps are things to be avoided wherever possible and are not necessary for a private house. For hotels, clubs, or any places where exceptionally large quantities of greasy water are discharged, grease traps are practically a necessity, as the grease, in cooling, would tend to form a coating on the inside of the drain and so gradually reduce its diameter. They are also very desirable if the house is a rural one with its own sewage purification plant. There are two types, (1) those in which the grease is removed by hand, and (2) those in which it is broken up by a powerful flush of water and washed through the drain in its solid state. They will be dealt with under the heading of drainage, as they are only desirable in special cases.

Foot of Soil-pipe. Soil-pipes should be directly connected to the drain without the intervention of any trap other than those at the outlets of the closets. The method of making the connection depends upon the materials of which the soil-pipe and drain are composed. Thus, if the drain be of cast iron and the soil-pipe lead, the foot of the latter would be strengthened by means of a brass, copper or gunmetal ferrule or thimble, and a caulked lead joint made to the junction of the two, as shown at A in Fig. 299. If both soil-pipe and drain be of iron, the ordinary caulked lead joint would be used, as shown at B in the same illustration. If, however, the drain be of stoneware, with a lead soil-pipe, the joint would be made with the help of a ferrule, using cement mortar or bitumen instead of caulked lead. The pouring of molten lead into the socket would split it to pieces and, even if lead wool be used, the caulking would split the socket. The joint for this case is shown at C in Fig. 300. If the soil-pipe be of iron and the drain of stoneware, a cement or bitumen joint is all that is necessary, as at D.

The connection between a copper soil-pipe and an iron or stoneware drain is made by using a standard fitting for diameters up to 2 in., and a brass or copper ferrule bronze welded to the tube

for the larger sizes, the joint being then completed as in the case of lead soil-pipes.

It will be realised that the method, already described, of carrying down the waste pipes from baths, lavatories, sinks, etc., on the outside of buildings to gullies at ground level, before connecting them to the drains which take the discharge from soil-pipes, tends to make the buildings unsightly; especially is this so with lofty hotels, equipped with a basin in each bedroom and a generous allowance of water-closets, bathrooms and lavatories. In consequence, some changes are taking place.

Internal Ducts for Soil and Waste Pipes. First, there is a tendency, in the design of large buildings, to collect all vertical pipes in one or more vertical shafts, erected as part of the main structure, means of access for inspection and repair being provided at each floor level. Besides improving the external appearance of the building this method lessens the risk of freezing of waste pipes.

"One-pipe" Plumbing. Secondly, and of much greater importance, there is a tendency to adopt what is known as the "one-pipe" system, which has already been mentioned in this chapter. In this system the same vertical main pipe is made to serve as a soil-pipe and as a main waste pipe from baths, lavatories, etc.: the main pipe is, in fact, an extension of the drain up the wall of the building—most usually, but not necessarily, inside the wall of the building, as described above. Similarly one ventilation pipe will serve to ventilate fittings of all kinds—water-closets, baths, lavatories, etc. Strictly therefore there are two pipes in the "one-pipe system", a main waste pipe and a ventilation pipe, in addition to rainwater down pipes.

The system is in general use in the United States of America, where buildings are, generally speaking, higher than in this country. It is now coming into use in this country, being provided for in the by-laws of the London County Council and in the Model By-Laws, whose lead has now been followed by the by-laws of many local authorities up and down the country, particularly in the urban area.

The system obviously is likely to reduce cost of construction, and of maintenance, in buildings of some size, though perhaps not in the case of small houses, unless the sanitary compartments in them are very compactly arranged. Further advantages are that the main is kept constantly flushed, that the alkalis of soapy waste water will neutralise the acid character of closet discharges and so diminish corrosion, and that unhygienic, greasy gullies are

avoided. On the other hand, we have lost what was previously referred to as the first line of defence against the passage of drain air into bathrooms, kitchens and even bedrooms, and the trap in the fitting is the only barrier to the passage of foul air from the soil-pipe.

Where the one-pipe system is in use it is therefore doubly important that all traps shall have an ample water seal and that they shall be protected from siphonage by being of the anti-siphonic type, or fitted with anti-siphonage pipes leading to the main ventilation pipe; it is also most important that the plumbing generally shall be the best possible.

Fig. 301 shows the general arrangement and a particular point to be noticed is the treatment of the ground floor. If the building is a high one it is possible that synchronising discharges of several closets may cause the lower part of the main waste pipe to stand full of water for some height, the underground drain not being able to carry it away fast enough. If any fitting, such as a bath or lavatory basin, were below the level of the top of this standing water, and were connected directly to the main vertical pipe in the same manner as those on upper floors, foul water would be forced back through the trap into the fitting. This can be avoided by taking all ground-floor wastes directly to the underground drain, independently of the main waste pipe, as shown in Fig. 301.

A typical installation for a six-storeyed block of flats, with bath, lavatory basin and W.C. on each floor, would be likely to have a 4-inch soil-pipe, 3-inch main ventilating stack, 2-inch anti-siphonage branches from W.C., and 1½-inch wastes and vents from baths and basins. The saving in cost, in an example of this type and assuming first-class workmanship and materials, may be as much as 20 per cent. in favour of "one-pipe" plumbing. There would be little gain, however, when applying "one-pipe" plumbing to small suburban dwellings on two floors only.

"Single-stack" Plumbing. For some time past, at time of writing, the Building Research Station has been carrying out laboratory experiments and the London County Council has been trying out practical tests (at Fulham and elsewhere) on a further development of "one-pipe" plumbing, resulting in a still greater reduction of cost. The savings, of course, vary with the particular layout and the number of floors in the building being serviced, but the estimated relative costs of the plumbing for a five-storey block of flats, taking "standard" plumbing as 100 per cent., is as follows:

Standard plumbing	. .	100 per cent.
One-pipe plumbing	. .	80 ,, ,,
Single-stack plumbing	.	60 ,, ,,

Briefly, the "single-stack" system proposes to increase the "general-purpose" soil-pipe by half an inch in diameter over and above what would otherwise be necessary—(e.g. 4-inch soil-pipe instead of 3½-inch for an average case), to concentrate the sanitary fittings (both soil and waste) as closely around the "single stack" as possible on the various floors, and to omit completely anti-siphonage pipes, allowing the small addition to the diameter of the general-purpose soil-pipe to act as conduit to the descending water and channel for fluctuating air stream required for anti-siphonage purposes.

Observations through transparent plastic pipes in a full-scale model have shown that the water descending from W.C.'s, baths etc., is seldom sufficient to fill more than a small fraction of the pipe, and that the flow tends to descend along the inner walls of the pipe, while the air (shown by smoke in the model) tends to ascend by the centre of the pipe, which is free of water.

The most unlikely combinations of W.C. flushing, bath, basin and sink emptying on the several floors, and all made to synchronise, failed to do more than cause a water-level movement of more than ⅛ inch in the traps of fittings not being used or flushed, provided certain precautions in design were carried out. Those precautions were:

1. W.C. traps should have a minimum seal of 2 inches and an outlet not exceeding 3½ inches.

2. W.C.'s and soil fittings should branch into the soil-pipe with a curved junction of 2 inches radius.

3. Waste fittings should be trapped with a minimum seal of 3 inches.

4. Basins should have a trap and waste pipe of 1¼ inch diameter and a maximum length of branch of 5 feet 6 inches.

5. Baths and sinks should have a trap and waste pipe 1½ inch diameter and a maximum length of branch of 7 feet (owing to the slower rate of draining tending to refill trap even if siphoned).

6. Ground-floor fittings, to discharge into soil-pipe at least 3 feet above level of drain invert (to avoid backing up) or to be connected directly into drain at a level lower than the soil-pipe junction.

7. If "single-stack" to some fittings on more than five floors, a "relief" anti-siphonage pipe, 2 inches in diameter, to be fitted to a

ground-floor W.C. outlet, and carried up, without branches to any other fittings, to rejoin the soil-pipe above the level of the highest branch, or to be allowed free vent at eaves level if more convenient.

8. The "single-stack" soil-pipe should join the drain at its base by means of an easy bend (radius about twice the diameter of the pipe).

9. Until further experiments have been carried out on tall buildings, it is suggested that extra precautions should be taken to prevent siphonage of waste or soil branches serving fittings on the sixth and higher floors.

It must be kept in mind that the single-stack system at date of writing (June 1956) is not permitted by any known by-laws in this country, but the L.C.C. is very satisfied with its experiments and appears likely to modify its by-laws to permit its use in the near future. If it does so, it is probable that the Model Code and local by-laws up and down the country will follow its example. It is a case where students should keep a watchful eye on the professional papers to watch for further developments.

Having dealt with the waste matter down to ground level, the next chapter will deal with the underground drainage.

CHAPTER IX

The Building—Its Drainage

Early Drains. Little seems known of the drainage of the past. The Romans used sewers, and presumably, therefore, drains, but there seems no record of the use of drains in England until the time of Inigo Jones, in the seventeenth century.

Principles of Design for Good Drains. Sanitary engineers and other interested people will get a good deal of help here from the B.S. Code of Practice (No. 301 on Building Drainage), published by the British Standards Institution.

The keynote of all good sanitary work is simplicity and accessibility, and this applies with extra force to drainage. The foul matters should be removed from the vicinity of the building in as speedy a manner as possible, and there is no reason why this should not be done in every case, no matter how complicated the plan of the building, provided that the positions of the sanitary fittings be carefully arranged. As far as possible the following principles should be kept in mind:

1. The relative levels of the building and the sewer, or other point of outlet, should be accurately determined.
2. The pipes should be of non-absorbent materials and laid with watertight joints.
3. The diameters of the drains should be proportionate to the work they are called upon to do, with a 4 inch minimum diameter, as they have to carry solid matter as well as liquid.
4. The drains should be laid in straight lines between points of access, all changes of direction or gradient being open to inspection.
5. Branch drains should be as short as possible.
6. The drains should not pass under or too near to trees, owing to risk of damage by the roots.
7. There should be no right-angled junctions, all connections being made either in manholes, or with a "Y" junction or a bend so that the incoming drain points in the direction of the flow of sewage.
8. The drains should be laid to gradients which will ensure their being self-cleansing, or, if this is impossible, owing to the levels, automatic means of flushing should be provided.

9. All inlets to foul drains should be trapped, except in the case of soil-pipes, at the feet of which no traps should be used.

10. No drains should pass under buildings if it is possible to arrange them otherwise.

11. All entrances to drains should, where possible, be outside the building.

12. There should be ample means of access for inspection.

13. The system of drainage should be properly ventilated.

14. It is desirable to provide a separate system of drains to take the rainwater—indeed some local authorities make this compulsory.

Material for Drain Pipes. The foregoing points may now be dealt with in more detail. Pipes for underground drains may be of glazed stoneware, of glazed fireclay, or of cast iron protected against corrosion. The circumstances under which either should be used require consideration. The pipes of stoneware or fireclay are not so strong as those of iron, and are not so fitted to withstand the vibration of heavy traffic such as is so general in our large towns. Further, they are only from 2 to 3 feet long, as opposed to 6 to 12 feet, the lengths in which iron pipes are readily obtainable. This means that the iron drain has about one-quarter the number of joints that a corresponding drain of stoneware would have in any ordinary case, apart from which the caulked lead joint of the iron drain is stronger than any joint in general use for stoneware.

Drains under Buildings. It will be seen, therefore, that, for drains under or near buildings, and near heavy traffic, iron drains should be used. The only reason that they are not in such general use is that they are about twice as expensive as stoneware drains. The joint usually employed for iron drain pipes is the caulked lead joint, made exactly as described for iron soil-pipes in Chapter VIII.

Standard weights and dimensions are indicated in B.S 437 while cast-iron drain fittings to correspond are to be found in B.S. 1130.

Protection of Iron Pipes against Corrosion. It is important to note, however, that there are some purposes, even in the face of the foregoing remarks, for which iron drains, as at present obtainable, are entirely unsuitable. The pipes are protected against corrosion by three principal processes: (1) By the Angus Smith process (usually specified as "coated" pipes); (2) by the Barff or Bower-Barff process; and (3) by giving them a glass-enamel lining, all of which have been previously described. Neither of these protective coatings is of much value with sewage containing strong

acid solutions, such as one might get from certain trade processes. Thus, experiments have shown the following results from the use of weak solutions of sulphuric acid.

A pipe treated by the Angus Smith process was tested with a 0·5 per cent. solution of acid for a period of twenty-four hours, at the end of which the coating was peeling off, leaving the pipe without protection. The same percentage solution destroyed the protective coating of a Barffed pipe in the same period. The glass-enamelled surface of another pipe was completely destroyed by a 1 per cent. solution in the same time, whereas a salt-glazed fireclay pipe withstood, without injury, a 5 per cent. solution for the twenty-four hours.

These results show that the nature of the sewage to be carried must receive careful consideration before using an iron drain for a factory building.

Acid or Alkaline Discharges from Factories. It should be noted that where by-laws have been made under the Public Health (Drainage of Trade Premises) Act, 1937, it is a serious offence to discharge trade effluent containing acid or alkali in harmful proportions into the public sewer.

Local authorities are becoming very active in their control of both the quality and quantity of effluent and most modern industrial undertakings having acid or alkaline waste water to get rid of have neutralising plant to correct the *p*H value of their waste water before it enters even their own drainage system. In the case of acid waters the waste is conveyed to the neutralising plant in acid-resisting stoneware pipes.

Stoneware and Fireclay Pipes. The clay for stoneware pipes comes chiefly from Dorsetshire and Devonshire and that for fireclay pipes chiefly from the Midlands and North of the Scottish border. Their manufacture will be described in a later chapter, but the main points of difference will be described here. A good stoneware pipe is almost completely non-absorbent, even when unglazed, whereas a fireclay pipe, on fracture, shows a very absorptive surface.

Salt-glazed stoneware drainpipes are most commonly used in the south, and are better than fireclay for normal use owing to their dense, non-absorptive substance, but in Scotland this would usually entail greater expense in transport, and fireclay is more commonly used for the purpose but the pipes are given an interior glass (vitreous) enamelling in addition to the salt glaze, which makes them perfectly suitable for drainage work, and even better able to stand up to an acid effluent, owing to the double glaze.

Such pipes are known as "salt-glazed, glass (vitreous) enamelled drain pipes", and are included in B.S. 540, while drain fittings of the same class, as well as those of salt-glazed ware, are included in B.S. 539.

British Standard Pipes. The British Standards Institution have issued specifications (B.S.S. 65) for these pipes and a corresponding one for the fittings to be used in conjunction with them (B.S.S. 539). It is thus possible for the architect or sanitary engineer to specify either "British Standard Salt-glazed Pipes" or "British Standard Tested Salt-glazed Pipes". In the former case every pipe is expected to comply with the specification and can be rejected if it does not do so, but only a small proportion of the pipes have actually been tested at the manufacturers' works; in the latter case every pipe will have been tested by hydraulic test by an inspector, and stamped as a sign that it does comply. The hydraulic test referred to is that it will withstand an internal pressure of 20 lb. per square inch for five seconds without fracture or leakage.

"Tolerances". The thickness, permissible deviation from that thickness, permissible deviation from standard diameter, depth of socket, and permissible deviation from straightness in a 3-foot length, are specified as follows:

Diameter	Deviation from Diameter	Thickness	Deviation from Thickness	Depth of Socket	Deviation from Straightness
4 in.	$\frac{1}{8}$ in.	$\frac{1}{2}$ in.	$\frac{1}{16}$ in.	2 in.	$\frac{5}{16}$ in.
6 ,,	$\frac{3}{16}$,,	$\frac{5}{8}$,,	,,	$2\frac{1}{4}$,,	,,
9 ,,	$\frac{1}{4}$,,	$\frac{3}{4}$,,	,,	$2\frac{1}{2}$,,	,,
12 ,,	$\frac{5}{16}$,,	1 ,,	,,	$2\frac{3}{4}$,,	,,

The interior of the sockets and the exterior of the spigots are to be grooved with grooves of a depth of not less than $\frac{1}{16}$ inch, as a key for the cement mortar.

The pipes may be obtained salt-glazed inside and out, or salt-glazed on the outside and glass-enamelled inside if this is expressly specified.

Other diameters, intermediate between those named above, may now be obtained. The lengths are either 2 feet, 2 feet 6 inches or 3 feet, but pipes of small diameter are obtainable only in 2-foot lengths.

Joints for Drain Pipes. Stoneware or fireclay pipes are jointed in a variety of ways. The joint in general use is known as the ordinary cement joint, but there are other forms which consist partly of cement and partly of rings of bituminous composition. The latter may be divided into those having a single seal and double seal respectively and are used chiefly for sewerage rather than drainage work. As they are also obtainable for the latter purpose they may be here described. There are a great number of varieties of each type, but illustrations are given only of those possessing distinctive features.

Cement Joint for Drain Pipes. In the great majority of cases the ordinary cement joint is the most economical and is efficient. Fig. 302 shows the joint in section. The best method of making the joint is first to caulk the joint with a few strands of tarred gaskin or hemp, well rammed into the socket to prevent the cement finding its way to the inside of the pipe. This should be done by means of a proper caulking tool. The joint is completed by filling up the socket with cement mortar, composed of, say, one part of Portland cement to one of sand, as recommended in the Code of Practice for building drainage, though some local by-laws insist on 1 to 1, while others are satisfied with 1 to 2, extending the mortar beyond the socket to form a triangular fillet neatly bevelled off at an angle of 45°. The cement may be Portland cement to B.S. No. 12, or high-alumina cement or Portland blast-furnace cement may be preferred. (B.S. 915 and 146.) The sand should be good, clean sand, i.e. free from loam and ordinary earth. The mortar should be of the right consistency, as, if containing too much water, it will tend to fall to the lower side, or invert, of the pipe and leave the upper part imperfectly filled, whilst the underside of the triangular fillet may fall off.

It is seldom that any joint other than the simple spigot and socket joint filled with cement, and illustrated in Fig. 302, is used, but circumstances may sometimes warrant the use of one or other of the following joints.

Bituminous and other Forms of Drain Joint. Some surveyors prefer a joint with more elasticity than a cement joint possesses, and in such case use instead a bituminous mixture composed of bitumen and sand boiled together in a cauldron alongside the trench, and filled into the socket in a molten state by the aid of special moulds, or a rough mould made of clay placed around the joint temporarily.

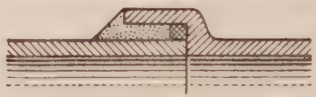
To prevent the possibility of the spigot dropping in the socket

owing to improper caulking with gaskin, or to the absence of such caulking, various modifications have been made to the form of socket. Thus Fig. 304 shows Doulton's Invert Shoulder joint, Fig. 303 what is known as the Free-flow pipe, and Fig. 305 the Archer joint. In the last named the cement is poured in, in a liquid state, through a hole at the top of the socket, there being another hole for the escape of the air. The best proportion is three parts of cement to two of water by volume.

Proprietary Forms of Drain Joint. We come next to special joints formed by the contact of rings of bituminous composition, moulded on the spigot and socket. Fig. 306 shows a section of the Stanford joint, while Fig. 307 represents Doulton's Self-adjusting joint, which is designed somewhat on the ball-and-socket principle. The ring in the socket is of parallel thickness and that on the spigot is segmental. The joint is made by smearing the ring on the spigot with tallow or some plastic compound.

In Fig. 308 is shown the section of a Double-seal joint made up of composition rings backed by cement mortar. Fig. 309 shows another form of Double-seal joint, differing in that it has a fairly large groove in the socket, to afford a key for the mortar. The Hassall Single-lined joint is shown in Fig. 310, a small fillet of clay being put round the mouth of the socket, and cement grout poured in to fill up the space. Another form of compound joint is the Parker, given in Fig. 311; it will be seen that the shape of the ring is such as to give a good key. Fig. 312 is the True Invert, having the rings at the mouth of the socket and the base of the socket exactly fitting the spigot. Fig. 313 is the Sykes joint in which a collar is formed on the spigot, there being a composition ring on it, against which the end of the socket abuts. Fig. 314 is the Hassall Double-lined, having two pairs of composition rings with a band of cement between; Fig. 315, the Solus, having two pairs of rings and two bands of cement; and Fig. 316 the Secure joint, having one pair of rings, but so formed as to produce a band of cement of dovetailed section.

The "Grouted Composite" joint, shown in Fig. 317, is a very secure joint and can be rapidly laid. A band of canvas goes nearly all round the joint, being secured by wire to the socket and spigot. There is a small space between the ends of the canvas, through which the cement grout is poured. The inner rings are of the form already described as the Doulton Self-adjusting joint, and the substantial backing of cement makes a very strong joint. The canvas probably perishes before long, but that does not matter,



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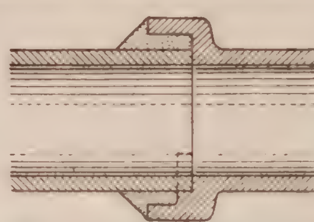

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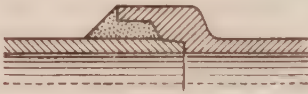

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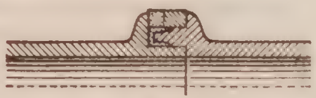

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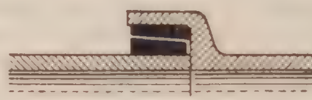

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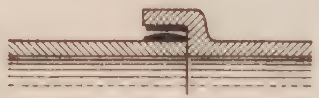

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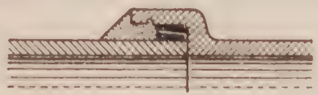

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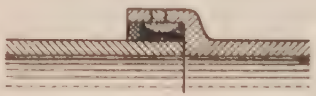

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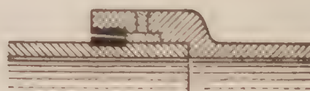

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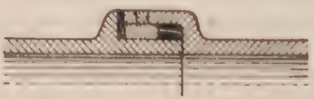

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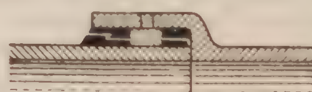

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as it has done its work. The pipes can be more rapidly laid than most of the more complicated joints.

A joint of an entirely different nature is shown in Fig. 318, and known as the Rubite. The pipes have no sockets but have annular grooves near to the ends, the joints being formed of a band of bituminous material termed rubite, poured into moulds temporarily placed round the joint, a little soft clay being smeared on the abutting ends in order to prevent the composition reaching the inside of the pipes and causing an obstruction. The joint has considerable elasticity and is therefore well able to resist the tendency to damage by reason of settlements.

Concrete Foundations for Drains. Whatever joint is used it is preferable that the pipes shall be laid on a bed of concrete 6 inches thick, 6 inches wider than the pipe on each side, haunched up to half the height of the drain, as shown in Fig. 364. This is required by the by-laws of the London County Council and those of many provincial towns, though rural authorities sometimes permit the omission of the concrete.

Size of Drains. Little need be said in reference to the diameters of drains. For a small house both branch and main drains should be made of 4-inch pipes. For a large house, the main drain should be 6 inches and the branches 4 inches in diameter. In the case of a very extensive drainage scheme a larger main drain might be found necessary, but it should always be remembered that the smaller the diameter of a drain, provided that it is large enough to carry off the requisite quantity of sewage, the more self-cleansing will it be.

Straight Runs for Drain Pipes. The necessity for laying drains in straight lines from point to point, both in plan and in section, has long been recognised, owing to the fact that in such case there is a minimum of retardation to the flow of sewage and that satisfactory means of inspection can thereby be obtained. It will be more convenient to deal with the construction and arrangement of the means of inspection, i.e. inspection bends and junctions, and inspection chambers or manholes, later on, as it can be better dealt with in conjunction with the question of disconnection from the sewer.

Short Branches. The reason that the branch drains should be as short as possible is that there are not such good facilities, as a rule, for their inspection as there are for the inspection of main drains. Also branch drains are seldom ventilated, so the shorter they are kept the smaller the available space for stagnant air. As has been shown, gullies are obtainable with access stoppers so

that a cleaning rod could be passed through to the manhole, or vice versa, but these gullies are not so largely used as they should be. When they are used, it is most important that they should not be tampered with by incompetent persons, owing to the risk of the stopper being insecurely replaced and thus leaving a ventilating opening to the drain at ground level and adjacent to the building—in fact, of negativing the value of the gully.

Most local by-laws require branch drains over 20 feet long and carrying "soil" to be ventilated, even if no soil-pipe discharges into it.

Damage done by Tree Roots. Considerable damage is often done to drains owing to the roots of trees exerting sufficient force, in expanding, to crack the pipes, particularly if of fireclay. Not only is the pipe cracked, it is often burst in and a stoppage caused by the earth and the roots penetrating.

No Right-angled Junctions. If a main pipe, with liquid flowing through it, has a branch pipe connected to it at right angles, two things occur: (1) The velocity of flow in the main pipe is slightly checked, and (2) the liquid flowing from the branch pipe runs straight *across* the main pipe and rebounds, instead of its force being spent in aiding the flow along the main pipe. Both these points are overcome by making the connection by a bend pointing in the direction of flow in the main pipe.

Self-cleansing Gradients. We may next consider the question of gradient. To be self-cleansing, house drains should have such inclination as will produce a minimum velocity of 3 feet per second. If this cannot be obtained, automatic means of flushing should be provided. The depth of the sewer, into which the house drain is to be connected, is one of the controlling factors in determining the inclination and, in the erection of new property, the level of the lowest point from which water or sewage has to be conveyed should be so adjusted to the level of the sewer as to allow of an inclination that will produce a self-cleansing velocity in the drain throughout its whole length. On the other hand, it should be pointed out that too steep a gradient is almost as bad as one which is too flat, as there may then be insufficient depth of sewage to keep solid matters floating.

Maguire's Rule. There is a very simple rule, known as Maguire's, for obtaining the most suitable gradient for drains of different diameters. It is that the gradient shall equal 1 in (diameter in inches × 10). Thus, a 4-inch drain should have a fall of 1 in 40, 6-inch, 1 in 60, and 9-inch, 1 in 90, or thereabouts.

It is, however, seldom that these ideal gradients are suitable to

the available fall of the land, and any gradient between *twice* and *one-half* the gradient according to Maguire's rule will generally be permissible.

Drain Calculations. We can now deal with methods of determining the gradient necessary for any particular set of conditions, the velocity produced by any particular gradient, and the amount discharged by drains of various sizes laid at varying gradients.

One of the best-known formulae, equally applicable to a stream or river, is that known as Chezy's, expressed as follows:

$$V = C\sqrt{RS},$$

in which V = velocity of flow in feet per second,

C = a coefficient,

R = hydraulic mean depth

$= \left(\frac{\text{sectional area of flow}}{\text{wetted perimeter}}\right)$ in feet,

$S = \frac{\text{fall}}{\text{length}}$ (sometimes given as "sine" of slope).

Various authorities have given different values for C, among the principal being Beardmore's 94·2, Eytelwein's 93·4, and Downing's 100. The coefficient has not, however, a fixed value, as it must depend on the degree of roughness of the sides or bed of the pipe or stream.

It has been shown that the true value of C in Chezy's formula is $\sqrt{\frac{2g}{f}}$, in which

g = the gravitation unit = 32·2, and
f = the coefficient of friction.

For a good clean stoneware pipe drain the value of f may be taken as 0·0065, which gives, from the formula just shown, the value of C as 99·5. For all practical purposes, therefore, Downing's coefficient of 100 may be used.

A formula largely used at one time, and known as Eytelwein's, is

$$V = 55\sqrt{\text{H.M.D.} \times 2F},$$

in which V = velocity of flow in feet per minute,

H.M.D. = hydraulic mean depth in feet,

F = fall in feet per mile.

This formula agrees with that of Chezy if the value of C in the latter be taken as 94.

No matter which formula be used for finding the velocity, the discharge is found by the simple formula

$$Q = AV,$$

in which Q = quantity discharged in cubic feet per second.

A = sectional area of flow in square feet, and

V = velocity of flow in feet per second.

Drains are not always full, and if spoken of as flowing one quarter full, it is commonly understood to mean "full to the extent of one-quarter of its depth or diameter", and *not* "full to the extent of one-quarter of its sectional area".

Hydraulic Mean Depth. If flowing full or half-full the H.M.D. $= \left(\frac{\text{diam.}}{4}\right)$ feet, a statement which can be readily proved, thus:

$$\textit{If full}, \text{ H.M.D.} = \frac{\text{sectional area}}{\text{wetted perimeter}}$$

$$= \frac{\text{area of circle}}{\text{circumference}}$$

$$= \frac{3{\cdot}1416 \times \text{radius}^2}{2 \times 3{\cdot}1416 \times \text{radius}}$$

$$= \frac{\text{radius}}{2} \text{ or } \frac{\text{diameter}}{4}.$$

$$\textit{If half-full}, \text{ H.M.D.} = \frac{\frac{1}{2} \text{ area of circle}}{\frac{1}{2} \text{ circumference}}$$

which it will be seen must give the same result as the above, owing to the $\frac{1}{2}$ cancelling out in numerator and denominator.

If the drain is flowing with a depth equal to any other proportion of its diameter, the H.M.D. must be taken from a table, or worked out as follows:

Example.

Find the H.M.D. for a 9-inch drain flowing

(*a*) one-third full, and (*b*) two-thirds full.

(*a*) Let Fig. 319 illustrate the case in section.

The depth EC will be 3 inches, and DE will be 1·5 inches. First find the wetted perimeter, i.e. the arc ACB.

The cosine of the angle ADE $= \frac{DE}{AD} = \frac{1 \cdot 5}{4 \cdot 5} = \frac{1}{3}$; so that $\angle$ ADE $= 70° \, 32'$, and $\angle$ ADB $= 141° \, 4' = 141 \cdot 067°$.

$$\text{Arc ACB} = \frac{141 \cdot 067}{360} \times \text{circumference of circle}$$

$$= \frac{141 \cdot 067}{360} \times \pi \times 9 = 11 \cdot 08 \text{ in.}$$

The sectional area of flow equals the area of ACBD, minus the area of ADB

$$= \frac{\text{Arc ACB} \times \text{DC}}{2} - \frac{\text{AB} \times \text{DE}}{2}.$$

Now AE $=$ AD sin $70° \, 32' = 4 \cdot 5 \times 0 \cdot 9428 = 4 \cdot 24$ in.; so that AB $= 8 \cdot 48$ in.

$$\text{Area of ACBD} = \frac{11 \cdot 08 \times 4 \cdot 5}{2} = 24 \cdot 93 \text{ sq. in.}$$

$$\text{Area of ADB} = \frac{8 \cdot 48 \times 1 \cdot 5}{2} = 6 \cdot 36 \text{ sq. in.}$$

$$\text{Area of segment ACBE} = 24 \cdot 93 - 6 \cdot 36 = 18 \cdot 57 \text{ sq. in.}$$

$$\text{H.M.D.} = \frac{\text{sectional area}}{\text{wetted perimeter}} = \frac{18 \cdot 57}{11 \cdot 08}$$

$$= 1 \cdot 68 \text{ in., or } 0 \cdot 14 \text{ ft.}$$

(*b*) The case where the sewer is two-thirds full is shown in Fig. 320.

$$\text{Cos} \angle \text{ADE} = \frac{DE}{AD} = \frac{1 \cdot 5}{4 \cdot 5} = \frac{1}{3},$$

so that $\angle$ ADE $= 70° \, 32'$, and $\angle$ ADB $= 141° \, 4' = 141 \cdot 067°$.

The reflex angle ADB (i.e. sum of angles ADC and CDB) $= 360° - 141 \cdot 067° = 218 \cdot 933°$.

$$\text{Arc ACB} = \frac{218 \cdot 933}{360} \times \text{circumference}$$

$$= \frac{218 \cdot 933}{360} \times \pi \times 9 = 17 \cdot 19 \text{ in.}$$

The sectional area of flow is the area of ACBD, plus the area of ADB.

$$= \frac{\text{Arc ACB} \times \text{DC}}{2} + \frac{\text{AB} \times \text{DE}}{2}.$$

Now AE = AD sin 70° 32′ = 4·24 in., as before; so that AB = 8.48 in.

$$\text{Area of ACBD} = \frac{17{\cdot}19 \times 4{\cdot}5}{2} = 38{\cdot}68 \text{ sq. in.}$$

$$\text{Area of ADB} = \frac{8{\cdot}48 \times 1{\cdot}5}{2} = 6{\cdot}36 \text{ sq. in.}$$

Area of segment ACBE = 38·68 + 6·36 = 45·04 sq. in.

$$\text{H.M.D.} = \frac{\text{sectional area}}{\text{wetted perimeter}} = \frac{45{\cdot}04}{17{\cdot}19}$$

$$= 2{\cdot}62 \text{ in.} = 0{\cdot}22 \text{ ft.}$$

Abbreviated Hydraulic Tables. The following table gives the values of both the H.M.D. and the sectional area of flow, the latter being required when finding the discharge. The letter D throughout the table stands for diameter of drain, or sewer, in feet. As we shall, later, have to deal with sewerage, the figures for sewers of egg-shaped section have been here included. The egg-shaped section is seldom met in modern practice.

Sectional Form of Drain or Sewer	Pipes Flowing							
	⅓ Full		½ Full		⅔ Full		Full	
	H.M.D.	Sec. Area	H.M.D.	Sec. Area	H.M.D.	Sec. Area	H.M.D.	Sec. Area
Circular	$0{\cdot}186D$	$0{\cdot}229D^2$	$0{\cdot}25D$	$0{\cdot}393D^2$	$0{\cdot}291D$	$0{\cdot}556D^2$	$0{\cdot}25D$	$0{\cdot}785D^2$
Egg-shaped	$0{\cdot}206D$	$0{\cdot}285D^2$	$0{\cdot}268D$	$0{\cdot}509D^2$	$0{\cdot}316D$	$0{\cdot}756D^2$	$0{\cdot}29D$	$1{\cdot}149D^2$

An example will show the use of the formula and the foregoing table:

Example.

Determine the gradient at which a 6-inch drain must be laid in order that the velocity of flow through it shall be 4 feet per second when only one-third full. Also find the quantity, in cubic feet per minute, that it will discharge when flowing two-thirds full at that gradient.

$V = c\sqrt{rs},$

$c = 100,$

$s = \frac{\text{fall}}{\text{length}} = \frac{1}{x} = \text{gradient}.$

$r = \text{H.M.D.} = 0{\cdot}5 \times 0{\cdot}186$
$= 0{\cdot}093.$

$v = 4.$

Transposing the formula we get:

$$V = 100\sqrt{rs},$$

$$\frac{V}{100} = \sqrt{rs},$$

$$\frac{4}{100} = \sqrt{0{\cdot}093 \times s},$$

$$\frac{16}{10{,}000} = 0{\cdot}093s.$$

$$\frac{16}{10{,}000 \times 0{\cdot}093} = s = \frac{1}{x}.$$

$$\therefore x = \frac{10{,}000 \times 0{\cdot}093}{16}$$

$$= 58{\cdot}12.$$

$\therefore$ Gradient $= 1$ in 58.

When $\frac{2}{3}$ full, the velocity will be more than 4 feet per second.

$r = 0{\cdot}5 \times 0{\cdot}291 = 0{\cdot}146.$

$s = \frac{1}{58}.$

$$\therefore v = 100\sqrt{0{\cdot}146 \times \frac{1}{58}}$$

$$= 100\sqrt{0{\cdot}00252}$$

$$= 100 \times 0{\cdot}05$$

$$= 5 \text{ ft. per sec.}$$

$$Q = 0{\cdot}556D^2 \times 5 \times 60$$

$$= 0{\cdot}556 \times 0{\cdot}5 \times 0{\cdot}5 \times 5 \times 60$$

$$= 41{\cdot}7 \text{ cu. ft. per minute.}$$

Flushing Drains with Insufficient Fall. Where the available fall is insufficient to give a self-cleansing velocity, various means are available for automatic flushing. Fig. 321 shows a section through a siphonic flushing gully suitable for a branch drain. It is made of glazed stoneware and is designed to hold up the collected waste water from sinks, lavatories, or rainwater pipes, releasing it with considerable flushing force when sufficient water has accumulated to start the siphonic action.

Tipping Tanks. Fig. 322 shows a tipper arranged for the same purpose at the head of a drain, the mouth of the drain being enlarged to utilise the flushing power to the best advantage. This is done by the use of tapering pipes. Thus, that next to the tipper is tapered from 12 to 9 inches, the next one from 9 to 6 inches, and the third from 6 to 4 inches. The tipper is provided in a cemented brick chamber, with a concrete floor finished with a cement surface, and is fed by waste pipes from baths, lavatories, etc. It has a capacity of about 20 to 25 gallons.

Flushing Tanks. The best method of flushing a main drain is by means of an automatic tank. There are various patterns of these, but Fig. 323 shows a section of the Field flushing tank. For small sizes it can be made of iron, and for large, of a combination of brickwork and iron. It is usually placed adjacent to a manhole at the head of a main drain, and can be supplied with water from a water main, or rainwater can be utilised. Such tanks do not work satisfactorily with dirty water, such as sink wastes.

The construction and working is as follows. There are two compartments to it, an upper main tank and a smaller one, termed a trapping box, below. The lower one contains a small quantity of water for the purpose of trapping, or sealing, the lower end of a pipe which passes up through the water in the tank above. This pipe is covered by a "dome" which reaches nearly to the floor of the main tank, being supported on feet. As the water rises in the tank, it can also rise under the dome and will at first rise an almost equal amount both inside and outside. Between the surface of the water which is rising under the dome, and the surface of the water at the foot of the pipe, air is being gradually compressed and, when the water under the dome reaches the mouth of the pipe, it falls over through this highly compressed air, displacing, by agitation, the resistance offered by the seal at the foot of the flushing pipe. This sets up the siphonic action and the whole contents of the main tank are then driven out by atmospheric pressure. It should be noted that the mouth of the pipe has a funnel-shaped inlet. Were it not for this, the water would form a sort of lining to the pipe, running away to the trapping box without causing the breaking of the seal at the foot. At the end of the flush the trapping box retains sufficient water to restore the seal.

Size of Flushing Tanks. The capacity of the flushing tank depends on the diameter of the drain and the length, and the following table gives an idea of the necessary provision:

Flushing Tanks

Diameter of Drain	Length	Capacity in Gallons	Diameter of Flush Pipe
4 in.	50 ft.	30	3 in.
4 ,,	100 ,,	60	3 ,,
6 ,,	50 ,,	60	4 ,,
6 ,,	100 ,,	100	4 ,,
9 ,,	100 ,,	200	6 ,,
9 ,,	150 ,,	300	6 ,,

Drains with Too Steep a Fall. If the gradient of drain is too great and the velocity too fast, there may be a tendency for the liquid to run away from the solid matter, leaving it stranded, though the risk is not great unless the slope is of the order of 1 in 15 or 20, and in any case, the fault is not nearly so serious as when the gradient is too flat.

The remedy is to make use of a "drop manhole" or "ramp" as shown in Figs. 357 and 358. These are sometimes referred to as "tumbling bays".

Grease Traps. In amplifying the general principles underlying the design of a system of drainage, we come next to the trapping of inlets to drains. Generally speaking, the inlets are trapped by the use of a gully, various types of which have been described in Chapter VIII. Sometimes grease traps are used, but these are only necessary for large institutions and hotels from which much greasy water is discharged, and for country houses having bacterial installations for the disposal of the sewage. The grease has to be intercepted in the latter case as it is prejudicial to the bacterial treatment.

One form of grease trap is shown in Fig. 324. It will be seen that it has a solid cover, and an inspection stopper on the outlet. The dotted line shows the base of a perforated iron tray capable of being lifted out by means of a handle at either side, one handle being shown in the sketch. The accumulation of grease can be lifted out by this means, and it is important that such fittings should receive regular attention. Some such grease trap as that shown would be used where the grease must be intercepted from the drains.

Flushing Gulleys. Another form of grease trap is the flushing grease gully which is illustrated in Fig. 325. It is arranged to take two or three waste pipes, and has a flushing rim connected to an automatic flushing tank, which can be above ground and inside the building. It is in three pieces, the centre one being capable of being turned in any direction. The force of the flush breaks up the accumulation of grease and washes it through the drain.

A suitable type of automatic flushing tank for this purpose is shown in Fig. 326, the principle of it being very similar to that of the Field tank already described. In Fig. 326 the tank is shown fed by a ball valve, in which case a stop-tap is also needed to regulate the rate of filling. An alternative is to feed the tank by a bib-tap, as in Fig. 323, no other tap being then necessary. In either case it is generally better for the regulating tap to be such that it

can be turned only by a loose spanner, placed in the charge of a responsible person.

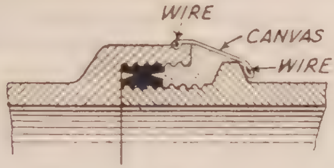
The only inlets to foul drains which are not trapped are those at the feet of the soil-pipes. These are directly connected to the drain to assist in its ventilation.

Drains under Buildings. Wherever it is possible to avoid it, drains should not be laid under buildings. A leaky drain is obviously a more serious thing under a building than a defective drain under a garden, apart from the expense and inconvenience in taking up floors, etc., for repairs. Further, if a drain passes under a wall, it is possible that, in settling, such wall will crush the pipes or cause other defects. This may be guarded against by forming a proper arched opening in the wall, just over the pipe, with a clear space between the two.

Gullies in Basements. All entrances to the drains should be outside the building if possible. One often finds gullies in the floors of old basement houses. A room may have been a wash-house and subsequently converted to other purposes, with the result that the gully has ceased to receive any water as originally intended. In such case it will, in time, lose its seal by evaporation, and ventilate the drain into the house. On ceasing to be used, a gully, and the drain attached to it, should be removed or, if this is difficult for any reason, the gully should be filled up with fine concrete, and cemented over. In some few cases entrances to the drain have to occur inside the building, such, for example, as where the building covers almost the entire site. In such examples there should be means of inspection at the foot of every waste pipe, provided with hermetically sealed covers.

Means of Inspection. In every system of drainage there should be ample means of inspection in the form of inspection bends or junctions, or proper inspection chambers or manholes. At the manhole at the lowermost end of the drain, just inside the boundary of the premises, a disconnecting or intercepting trap should be put to disconnect the drain from the sewer. In some places the use of the intercepting trap is optional, and there is much to be said for and against its use, but that point will be fully discussed later.

Inspection Bends. If the drain is not more than 2½ feet below the surface, means of inspection may be provided by an inspection bend or inspection junction. Fig. 327 shows a plan of the latter, in which two drains meet at a right angle. Junctions for drains meeting at other angles are of course obtainable. It will be seen that the point of junction is open, a socket pointing upwards from



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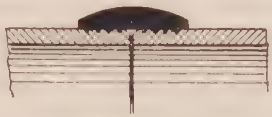

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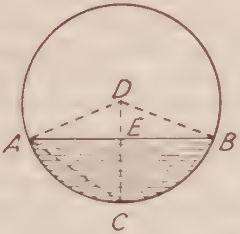

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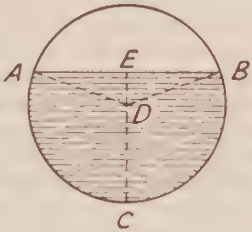

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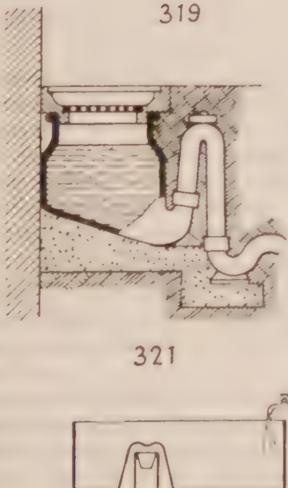

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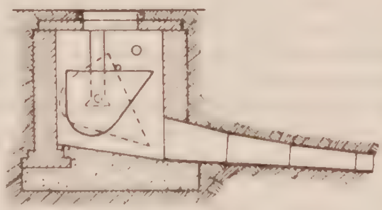

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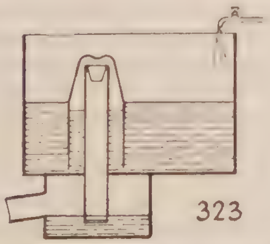

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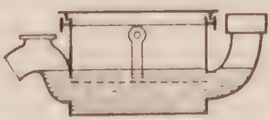

324

it and receiving the spigot of either a 15-inch or an 18-inch pipe, which is built in and carried up to ground level. It is there finished with a stone slab or small block of concrete around it, and provided with an air-tight cover. This is a cheap substitute for a manhole, but its use should be limited to a single junction and then only if the branch drain carries rainwater.

Inspection Chambers. In any other case, or if the depth of the drain is greater than $2\frac{1}{2}$ feet, a proper manhole should be used. The size will of course depend on the depth and the number of junctions. If only about 3 feet deep it will be easy to reach to the bottom of it, but if of greater depth it must be made large enough for a man to get inside and bend down. The size may therefore range from about 2 feet by $1\frac{1}{2}$ feet, up to $4\frac{1}{2}$ by $2\frac{1}{2}$ feet.

The manhole is usually formed with open channels in the floor of it, though there is much to be said for using closed channels, thus confining any foul air to the pipes, instead of making the manhole a receptacle for its collection. As ordinarily constructed, however, a manhole can be formed with brick or concrete walls, finished with cement rendering, or lined with salt-glazed bricks, which is much better for testing purposes, as the walls can then be made practically non-absorbent. The floor should be of concrete, and if open channels are used they should be of white glazed fireclay. Fig. 328 shows a plan, and longitudinal and cross-sections, of such a manhole floor. The plan shows two branch drains connected by means of white glazed channel bends. To prevent the sewage flowing over the sides of the bends at E and F, what are known as three-quarter section bends are used. There are many varieties of bend, but that shown in Fig. 329 is a good type. It has a three-quarter pipe section to prevent the water from a steeply inclined side branch entering with a sharp curve from banking up on the outside of the bend and overflowing the floor of the manhole, thus fouling it. This form is sometimes known as a "Baron Bend".

The cross-section CD in Fig. 328, shows the sides of the main channel benched up with concrete, so as to give a greater depth to it than would be furnished by the semicircular section of the straight channel. The longitudinal section A B shows the bends discharging about 2 or 3 inches above the bottom of the main channel, which prevents water backing up the branches when the main drain is running nearly full. A chute or enlarged entrance (Ch.) is sometimes provided at the outlet end to facilitate the passing of drain rods through the drain for cleansing purposes.

Top of Chamber. The top of the manhole may need to be

corbelled over to reduce its size, and finished with an airtight cover of galvanised iron. The cover should be of good thickness, in order to stand any reasonable traffic over it. There are many forms of joint for these covers. Some are merely kept down by their own weight, some are capable of being locked by a turn buckle, and others can be screwed down. The best (though rather expensive) type is to use a double cover such as that shown in Fig. 330. The lower cover fits into a deep groove and is of a domical shape. The moisture in the air of the drain condenses when it comes in contact with the cold iron cover, and the water trickles down its under side to the channel or groove and forms a sound water seal. Over this cover is another, fitting into a groove filled with grease, sand or plastic cement. The more usual form has the top cover and groove only and if sealed with grease as suggested is quite sufficient safeguard for normal use. Fig. 331 shows a good type of joint for a single cover, the grooves being filled with a jointing material as just described. Some types of cover are bedded on a rubber ring, but rubber soon perishes and is an unsuitable material. Fig. 332 shows the arrangement of a cover secured by gunmetal screws, and Fig. 333 shows a single seal cover, which is more usual.

Covered Inverts. A manhole with closed channels can be formed even if the drains are of stoneware. Figs. 334–335 show a plan and sections of such an example, together with the method of arranging the disconnection from the sewer. The plan shows the closed pipes with an access cover at the point of junction. The concrete would be filled in over them, and would slope down from all four sides to the rectangular cover in the centre, as shown in the section. The part section C-D, Fig. 336, shows more clearly how the channel is closed. An iron frame, protected against corrosion, is set in cement, in a socket formed in the stoneware. Inside this is a flat iron plate bedded on a prepared felt washer, and kept tight by a bolt passed through a crossbar which passes through openings at its two ends. Similar stoppers, but of course circular, could be used for the two openings marked 1 and 2 on the intercepting trap, or No. 1 opening could be utilised for a fresh-air inlet pipe.

Special Forms of Intercepting Trap. The intercepting trap shown is of special form owing to the nature of the manhole floor, but its general arrangement is similar to that of all intercepting traps.

Intercepting Traps with Covered Inverts. All intercepting traps intended to be used with covered invert manholes should have a

branch or socket (such as No. 1 on Fig. 335) but a little to one side of the centre line, so that the air-inlet pipe shall not obstruct the insertion and manipulation of drain rods if the length between the intercepting chamber and the sewer needs to be rodded.

Arguments for and against Interception. There is a good deal of difference of opinion among surveyors as to the desirability of using these traps or of omitting them, of which only the chief will be given.

Arguments in favour. 1. The trap keeps tainted sewer air out of the house drain.

2. The use of the trap enables each householder to keep complete control of his drain ventilation scheme. If there is an efficient F.A.I. and only one soil and vent pipe, all the air entering must pass through the entire length of the mains drain and out through the soil and vent, only the branch drains having no ventilation (a very good additional reason for keeping them short).

Arguments against. 1. If the trap is omitted, the local authority can ventilate the house drains and the sewers collectively as a single unit, utilising all the soil and vent pipes of a given group of houses for outlet ventilation and providing inlet ventilation at certain points along the sewer to complete the scheme.

2. That the majority of drain stoppages are caused at (and because of) the intercepting trap. This undoubtedly is true, though a well-designed intercepting trap of B.S. design, in a properly laid drain used in a normally reasonable way, will not cause obstructions.

For many years, in this country, local by-laws have compelled the installation of the intercepting trap and the fresh-air inlet just inside the boundary and as near to the public sewer as possible.

In recent years municipal engineers and surveyors have, in large measure, come to feel that the disadvantages of the trap outweigh the advantages and to-day an increasing number of local authorities, in their drainage by-laws, either make the use of the trap optional or forbid its use and that of the F.A.I. in the case of all new houses and buildings erected in their areas.

As the majority of districts still insist on the trap, the architect or surveyor must peruse the local by-laws before advising his client.

Interception from Cesspool or Septic Tank Essential. Whatever the opinions may be as regards drains discharging into public sewers, there is no doubt at all in the case of those discharging into cesspools or septic tank installations. Here, an intercepting trap and F.A.I. are essential.

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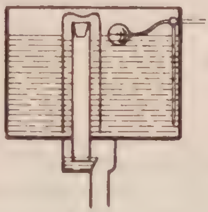

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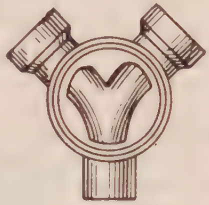

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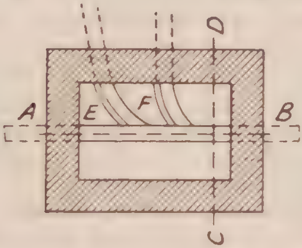
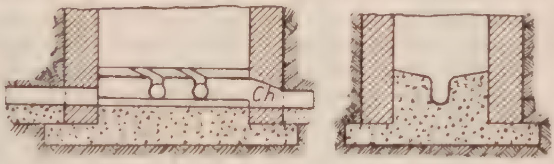
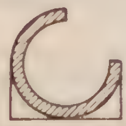


FLOOR OF INSPECTION CHAMBER. PLAN AND SECTIONS



SECTION A-B SECTION C-D

328



3/4 SECTION CHANNEL
329

DOUBLE MANHOLE COVER
330

DETAILS OF MANHOLE COVERS FOR DRAINS
DOUBLE SEAL. BOLTED COVER. SINGLE SEAL.
331-333

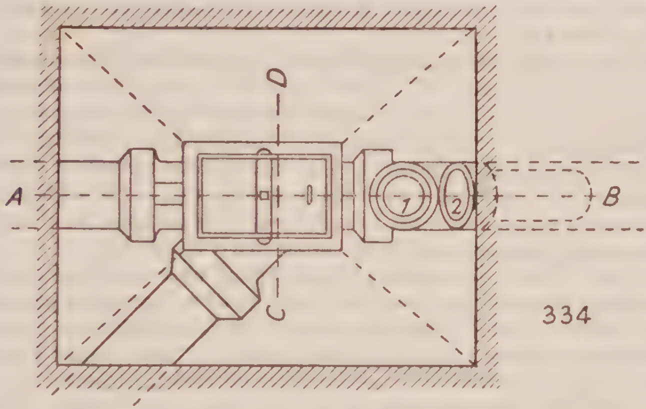
The present Model By-laws of the Ministry of Housing and Local Government leave it to the local authorities to decide whether in their local by-laws they shall require interceptors between drains and sewers, but if drainage is into a cesspool the Model By-laws insist on an interceptor, and most local authorities follow this lead.

The by-laws of the London County Council allow drains to be laid with or without an interceptor; if it is provided it must be as near the sewer as possible, must have a water seal of at least 2 inches, a clearing arm with a suitable secure stopper, and it must be in a manhole; if an interceptor is not provided any portion of the drain which is within or under a building must be of cast iron.

Design of Intercepting Traps. Fig. 335 shows an intercepting trap with a good seal and a cleaning arm for access to the short length of drain between the trap and the sewer. It is designed for stoneware drainage with covered in invert channels in the inspection chambers. It is important that such a trap should be set quite level and that there should be a drop or cascade at its entrance. Fig. 337 shows the B.S. type for use in the more usual type of open channel manhole, also for use with stoneware drains. There is a cascade at C and a small weir at W. The cleaning arm is marked C.A. and should have a very secure stopper at S. Much of the trouble in intercepting traps has been due to the defective fixing of the stopper. They have often been jointed by means of the Stanford and similar joints, but this has sometimes proved unsatisfactory where a blockage has occurred, as the stopper could not readily be removed to allow the accumulated sewage to run away, thus laying bare the trap and making it possible to get on with the cleaning of the obstruction. Sometimes the stopper has been fixed so loosely that a reverse rush of air from the sewer has pushed the stopper out to fall into the mouth of the trap, thus causing the blockage.

Alternative to Cleaning Arm Stopper. A circle of glass is sometimes used instead of the stoneware stopper usually provided. This can be firmly fixed with cement or putty. In the event of stoppage the glass can be readily broken to allow the dammed-up sewage to escape and a new circle of glass can then be cemented in when the clearance is complete and the floor of the manhole swilled out with a hosepipe. A rather better arrangement is to provide a mechanical stopper such as that shown in Figs. 339 and 340.

In both of these forms a chain is attached to the crossbar and provided with a ring which hangs on a hook on the manhole wall near the lid. On a blockage occurring, a pull of the chain releases



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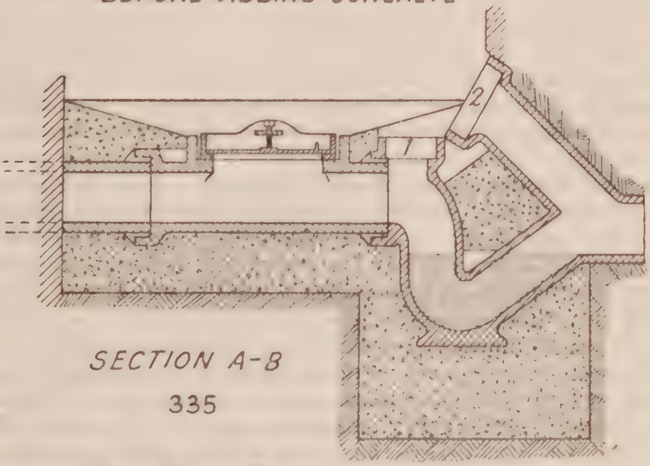
PLAN OF FLOOR
BEFORE ADDING CONCRETE



SECTION A-B

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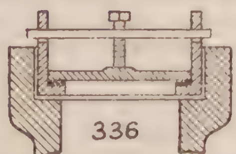


336

PART SECTION C-D

MANHOLE WITH
CLOSED CHANNELS
AND INTERCEPTING
TRAP

the stopper and the accumulated sewage. This is the form recommended by the British Standard Code of Practice on Building Drainage.

Points of a Good Intercepting Trap. A good form of intercepting trap should have a seal of not less than $2\frac{1}{2}$ inches, and hold only a relatively small quantity of water; average figures are: a 4-inch trap holds from $3\frac{1}{2}$ to $5\frac{1}{2}$ pints, and a 6-inch from 6 to 9 pints. The trap should have a drop down to the water at its entrance of about 2 inches in the case of a 4-inch intercepting trap and a little more in the case of a 6-inch trap to give a cascade action and to submerge light floating matters and force them down the drain.

The inlet should be made very steep or even vertical so as to help in this effect, while the outlet then leads up far more gradually to the weir or outlet, enabling heavy faecal matter to make its way up and over on its way to the sewer. These points are very pronounced in the British Standard Specification type.

Anti-flooding Interceptors. Fig. 341 shows a special type of interceptor, designed for use in positions in which the branch leading to the sewer is subject to tidal action or back flooding. It has a light ball which is held up against the inlet, on the tide forcing the sewage back up the drain. It will be seen that an air-inlet socket is provided at A, and an access stopper at S. This type has been used by H.M. Office of Works on the drains of public buildings near the Thames at Westminster, where, of course, the river is tidal.

Inspection Chambers for Special Positions. Fig. 342 shows a plan, and Fig. 343 a section, through a disconnecting chamber suitable for use under a street pavement, where the building comes right up to the edge of the street. It is just wide enough from front to back to give room for a man to enter, and about 5 feet wide the other way at the lower part; part of this 5 feet width is arched over, reducing the size of the chamber to merely an access shaft in the upper part. Deep manholes over 5 feet deep are often provided with built-in step-irons at vertical intervals of 12 or 15 inches, the step-irons being shown on plan in Fig. 342. They are subject to rusting by the condensation always present in manholes and the B.S. Code of Practice on Building Drainage discourages their use and advises a short ladder when inspection becomes necessary. The fresh-air inlet is shown formed in a chase or recess of the wall, marked F.A.I. on plan and section, finishing with a grating at a reasonable height above ground, the grating being backed by a flap of mica to prevent back draught. An airtight cover is provided at C.

Fig. 344 shows a longitudinal section through a disconnecting chamber on an iron drain, with a closed channel. The cover-plate can be either bolted down, or fastened by bars and screws, as shown in Fig. 346, the latter being a more readily accessible method.

The stopper of the cleaning arm is of similar construction. The surface cover can be of the ordinary airtight form, but as the channel cover is airtight, being provided with a prepared felt washer, the surface cover may take the form of an iron grating. The air-inlet pipe to the drain is also shown. In contracting the size of the manhole at the top, an arch or reinforced concrete slab can be used instead of the stone slab shown.

Fig. 345 shows the plan of the floor of an inspection chamber on an iron drain, receiving six branches, three on each side. The cover is held down by bars and bolts as before described, these being known as pinching bars, or it can be secured by means of bolts.

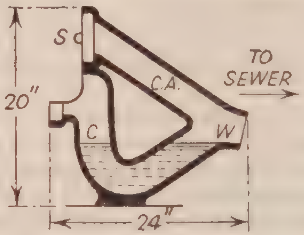
Fig. 346 shows a cross-section through the cover, the pinching bars passing through raised sockets at their ends. It will be observed that the cover is so shaped as to preserve the circular section of the pipe.

A form of intercepting or inspecting chamber which is not often met with is shown in section in Fig. 347. It is a form suitable for use with iron drainage, where there is a sub-basement and the sewer is at such a level that the drains are suspended from the ceiling of the sub-basement. It shows a bolted cover to the channel, and a similar one to the cleaning arm. The whole chamber is of iron and is carried by two of the floor joists.

Drain Ventilation. We come next to the question of ventilating drains. For many years it was an established principle that there should be at least two untrapped openings to a system of drainage, an outlet at the highest point, and an inlet for fresh air at the lowest, that is to say, at the position of the intercepting chamber.

The objects of ventilating a system of drainage are: (1) To prevent bad air from accumulating in the drains; (2) to divert any that may accumulate to places where injury to health or annoyance cannot be caused; and (3) to enable air to enter the drain when the water level falls and to leave the drain when the water level rises.

As has been seen, every drain should have a good fall. The vitiated air which accumulates inside the drain, and is often, owing to discharge of hot water from sinks, warmer than the atmosphere, and consequently more rarefied and lighter, will rise to the higher



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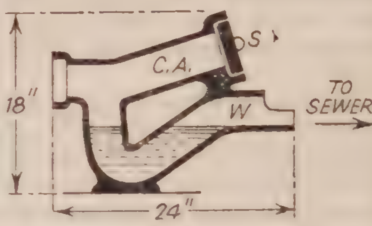

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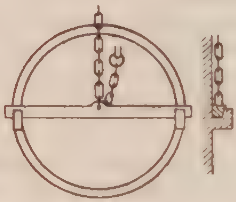

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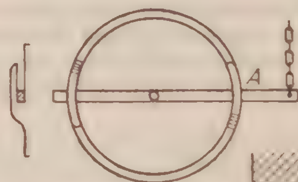

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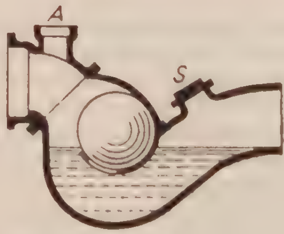

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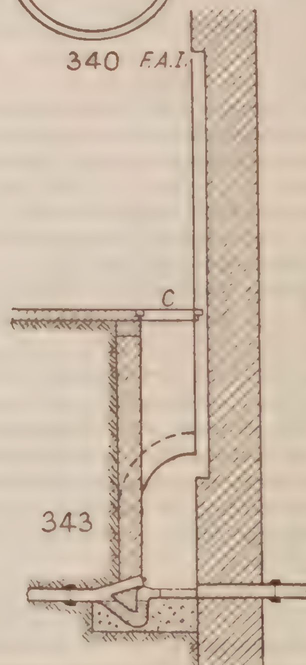

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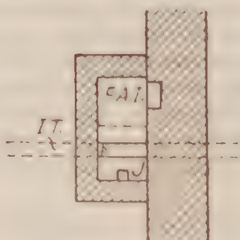

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end of the drain. If, therefore, an opening or outlet be made for this at the higher end, and an opening at the lower end to admit fresh air in its place, it is likely that a current of air throughout the drain will be produced, preventing the accumulation of bad air.

Natural Principles Involved. There should be an outlet ventilating pipe at the upper end of the main drain, and of every long branch drain, these pipes being carried well above the roof, with a minimum of bends so as not to obstruct the current. The upper ends of these pipes should be finished in as exposed a position as possible, and protected at the top by a domical copper wire grating, and should finish 3 feet above the head of any window within 10 feet laterally and usually above the eaves. By carrying the pipe up in this way, an exhaust draught is caused by the passing of wind across the top. The air at so high a point, being much more in motion than that close to the ground, is more rarefied and gives less pressure down the top of the pipe than exists at the bottom, hence the up-draught. Thus the action of wind tends to assist the natural ventilation by the rising of warm drain air, to which we have already referred.

If the vent pipe is a vent pipe only, i.e. does not also serve the purpose of a soil-pipe, it should be of the same diameter as that of the drain to which it is connected, and should be furnished with a rust pocket at its foot, the latter item having been already described and illustrated.

No matter how many outlet vent pipes there may be on a system of drainage, there should be only one inlet for fresh air, communicating with the intercepting chamber. If the latter is some distance from the building, and not near the road, an iron grating over the manhole will serve the purpose, but this is usually impossible to arrange. Therefore, one generally uses a galvanised iron pipe, with which there are two methods of dealing. Under either method the sectional area of the inlet should be approximately equal to the combined sectional areas of the outlets. Thus a 4-inch pipe should be used to supply only one 4-inch outlet, a 5-inch for two, a 9-inch for three, and so on.

The Fresh-air Inlet. One method of dealing with the fresh-air inlet pipe is to carry it up 3 or 4 feet from the ground and finish it with a mica flap inlet valve, placing the pipe well away from any windows in case the valve gets out of order and acts as an outlet. Fig. 348 shows a section through a good form of mica flap valve. It has a louvred front, and the flap of mica is set well back. It is hinged at the top and is shown slightly open at F in the sketch. This method is open to serious objection and formed one of the

points of inquiry by the Intercepting Trap Committee. It is often placed in unsatisfactory positions, and finished with an inferior valve, which soon gets out of order, the flap becoming set, either opening or closing the aperture permanently. In the case of cottage property, one often finds the front grating of the valve kicked in, and the flap missing. On good-class property this defect should not occur, but it is still indispensable that the valve should be of first-class quality if it is to remain efficient.

The second method is to carry up both inlet and outlets well above the roof. If an inlet is used at all, this is the only method that should be adopted in dealing with cottage property, and it is really a desirable one in all cases. At the same time it should be pointed out that the Intercepting Trap Committee conducted experiments which satisfied them that an inlet is unnecessary; in other words, that a drain requires a means by which air can go in and out, as the water level in the drain rises and falls, rather than a means of creating a through current of air.

Model By-laws on Drain Ventilation. The Model By-laws now require "at least one ventilating pipe not less than 3 inches in diameter, situated as near as possible to the building and as far as practicable from the sewer", and so leave the provision of an air inlet optional. On the other hand, the by-laws of the London County Council require two ventilation pipes if an intercepting trap is used, one as near as possible to the trap, the other as far as possible from it. If there is no interceptor, only one ventilation pipe is required.

Where expense has not to be considered, it is better to keep the rainwater separate from the sewage proper, in the drainage system. By this means the foul drainage can almost always be simplified, and the simpler it is in plan the better. At the same time, cases occur in which it is desirable to conduct the water from at least one rainwater pipe into the foul drainage, in order to increase the flush of a branch drain. The necessity of an adequate water supply for the success of any drainage system cannot be over-estimated.

We have already described in Chapter VIII the "air-disconnected drain", which is any drain carrying only clean water, disconnected from the foul drains by means of a trapped gully or "reverse-action intercepting trap" such as is illustrated in Fig. 338, and having its own ventilation inlets and outlets in the form of gully gratings and rainwater pipes.

CHAPTER X

The Building—Its Drainage
(*continued*)

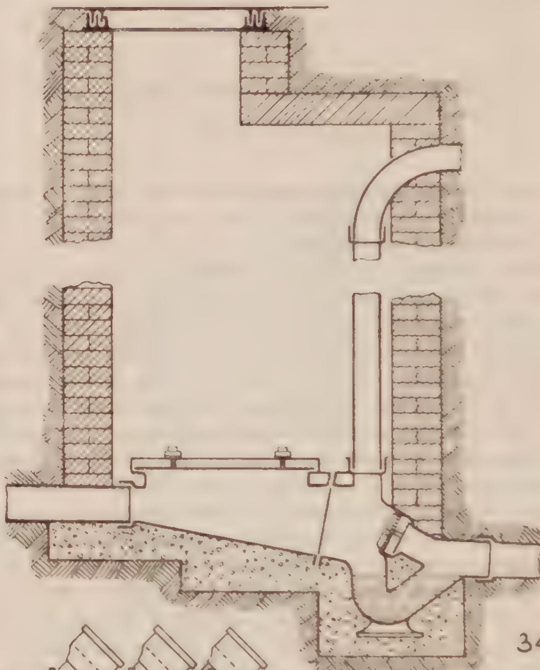
Layout of Drainage Schemes. Having fully considered the principles underlying the design of a drainage scheme, we may next deal with their application.

An accurate block plan of the building must be prepared, and the position of all soil, waste and rainwater pipes carefully marked on it, together with the position of any W.C. which is to be connected directly to the drain, such as a servants' closet on a ground floor, with no other closet over it. The arrangement of the drainage will, of course, depend on the character of the building, the nature of the site and the local by-laws. The local authority may require rain and surface water to be kept separate from waste water and "soil" or may permit all to be delivered into a "combined" sewer. They may require an intercepting trap and F.A.I. or the by-laws may forbid them or make them permissible. Again, with a terrace house, the main drain must necessarily pass under the building if the sewer is in the road in front, whereas in the case of a semi-detached or detached house the drains can usually be kept quite outside the site of the building.

Drainage Schemes for Terrace Houses. A few example plans may be given. Figs. 349 and 350 show block plans of two small terrace houses of different plan. The various inlets to the drain are lettered with distinctive letters and a reference table given to show their meaning. The same lettering will be adopted in further examples.

The heads of the gullies under the rainwater pipes are not shown owing to the smallness of the scale.

In both the examples under notice it is assumed that the local by-laws require an intercepting trap and F.A.I., and the intercepting chamber is placed in the front garden and the fresh-air inlet carried up behind the pier which carries the front railings. Channel gullies are shown taking the bath and sink wastes. In Fig. 349 the drainage from a yard gully at the back is turned into the drain from the servants' W.C., in order to assist in flushing it. The vent pipe is shown connected to the manhole at the back, but if the manhole had a closed channel it would have to be joined to



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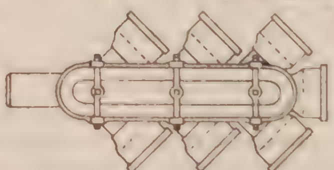

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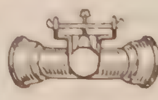

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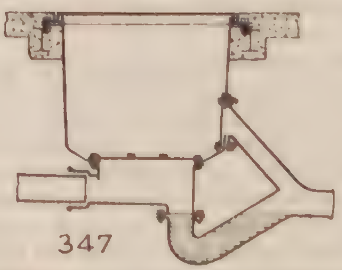

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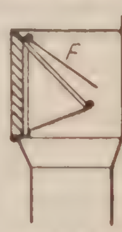

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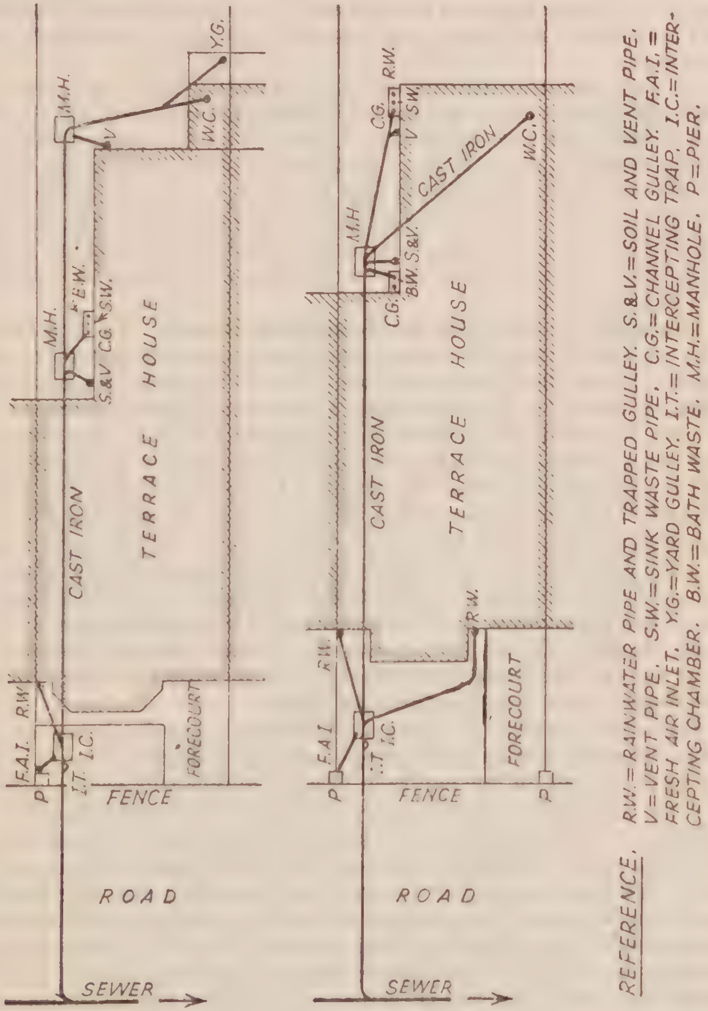


349 350

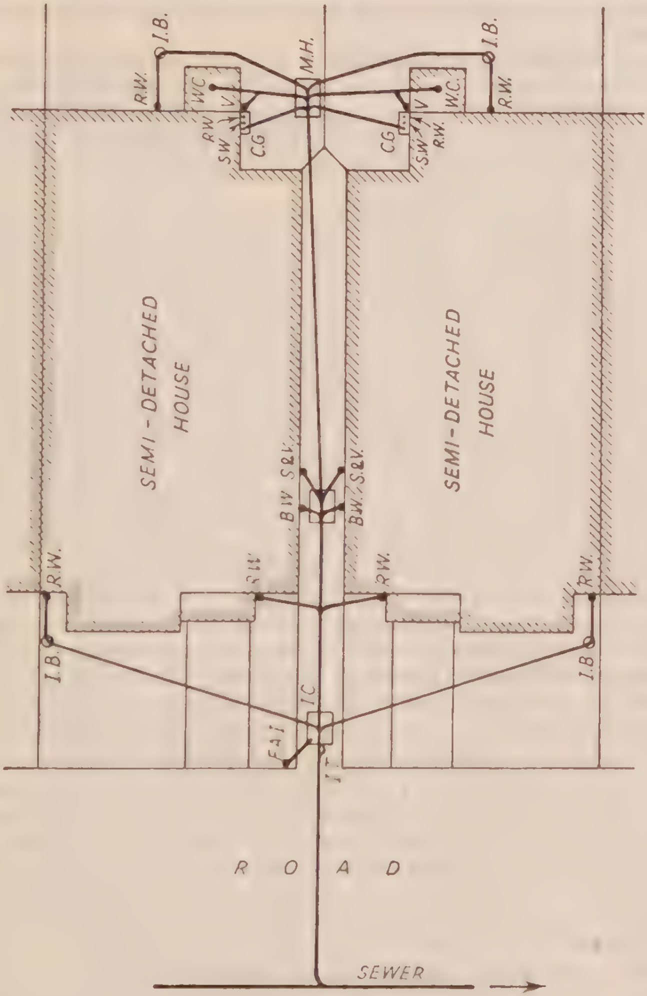
TWO EXAMPLES OF TERRACE HOUSE DRAINAGE.
(LOCAL BY-LAWS REQUIRE INTERCEPTING TRAP AND F.A.I.)

the drain. It would appear to have been better to put the vent pipe in the angle between the servants' W.C. and the main building, but it is shown otherwise owing to the existence of a skylight near that point.

In Fig. 350 the drain from the servants' W.C. is carried, in cast-iron pipes, under the back addition, for two reasons: (1) that the owner does not desire any manholes on the small grass plot at the back; and (2) that to proceed otherwise would mean two additional manholes, making four in all—rather a prohibitive item in the case of a small terrace house. In most cases, the soil-pipe would be regarded as a sufficient vent pipe for the system, but an additional one might be added where shown, adjoining the entrance of the sink waste.

Drainage Schemes for Semi-detached Houses. In Fig. 351 a pair of semi-detached houses are shown drained together, as is often done in the London district. It will be seen that a common passage leads to the tradesmen's entrances at the back of the houses and that the main drain is laid under this. Its course is not quite straight from end to end, as to make it so would bring the back manhole under the fence. Inspection bends are placed on two of the rainwater drains in each case. By placing the back manhole farther from the street, the rainwater drain at the back of each house might have been given one change of direction instead of two, but in this case the foul drains would have had to enter the manhole with a very sharp curve and the lesser evil has been chosen. It has been considered better, also, to connect the vent pipe to the drain from the W.C., a foul drain, rather than to the longer drain taking rainwater only.

Detached Houses. A detached corner house is shown in Fig. 352, separated from an adjoining house by a narrow passage. The peculiar placing of the sanitary fittings makes this case a difficult one to deal with economically, owing to the narrowness of the passage. The bath waste and soil-pipe might have communicated with the same manhole by placing the latter nearer the street, but the small space available between the manhole and the building would have caused very awkward junctions and the method shown is considered the better for this reason. It will be seen that the ground-floor W.C. is not under that on the floor above, and the drain from the former is therefore taken direct to the intercepting chamber. An additional manhole might have been put at the back to take the two sink wastes and the rainwater, but the increase in cost, over that of the arrangement shown, would not be justifiable. An inspection junction, I.J., is used at the connection of



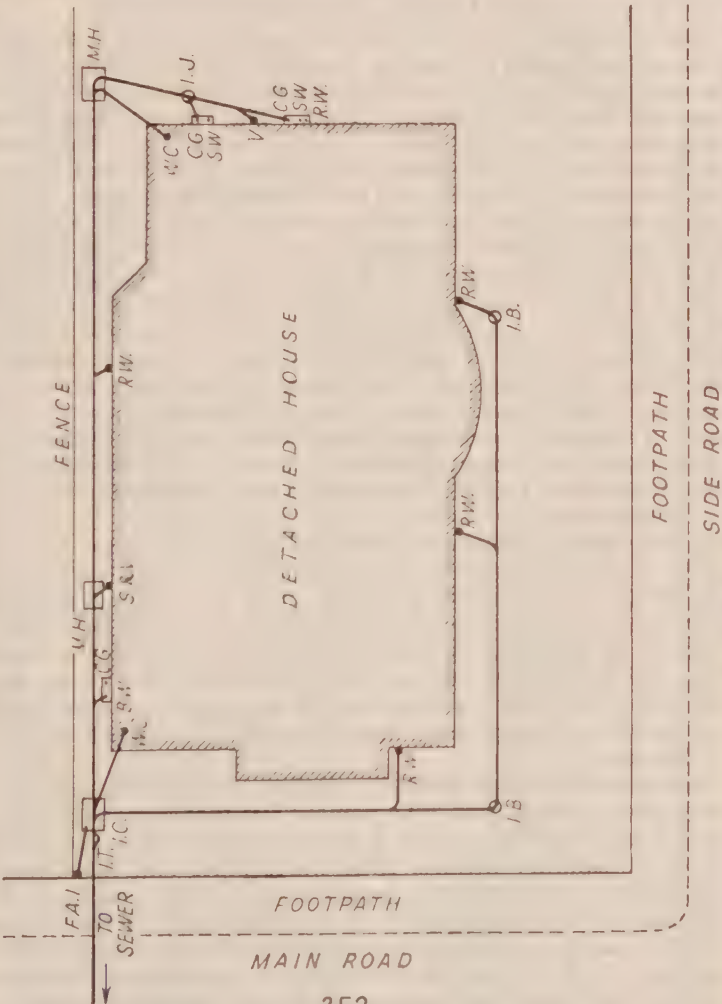
351
EXAMPLE OF JOINT DRAINAGE FOR SEMI-DETACHED HOUSES.
(LOCAL BY-LAWS REQUIRE INTERCEPTING TRAP AND F.A.I.)

the second sink waste. It will be seen that a good position is obtainable, in this example, for the vent pipe, right at the head of the system.

Use of Air-disconnected Drains. A modification of the arrangement shown would be to make the long rainwater drain from the right-hand side of the house an air-disconnected drain (see Chapter VIII) by putting in, close to the intercepting chamber, a trapped yard gully with side inlet for the drain and using untrapped gullies at the feet of the rainwater pipes.

Separate Drains for Surface Water and Foul Waste. Fig. 353 shows a much more extensive system than those already given, and illustrates the drainage of a fairly large bungalow on the separate system, with its own system of sewage disposal, the latter installation being situate some three or four hundred yards from the house. With the exception of those marked 6 inches, the drains would be of 4-inch pipes. As the septic tank system is used, grease traps are provided instead of channel gullies, the former being of the lifting tray type, as a flushing grease gully would not be permissible owing to the necessity of keeping grease out of the septic tank. At one point, to the south of the building, an ordinary flushing gully is provided, taking the outlets from two ordinary grease traps, and flushed by an automatic flushing cistern placed high up in the scullery. The intercepting chamber, being some considerable distance from the house, is covered by an iron grating to act as a fresh-air inlet. It will be seen that a vent pipe is provided to the head of each of the principal branch drains.

Working Sections of Drainage Schemes. Having prepared the plan of the drainage scheme, the next thing is the preparation of the working sections. The levels along the lines of the proposed drains must be carefully taken and the sections plotted, showing the existing surface of the ground. The method of taking the levels and plotting the sections is beyond the scope of the present work, but Figs. 354–356 give examples of completed sections after the lines of the proposed drains, positions of manholes, etc., have been added. They refer to the drainage of the bungalow shown in Fig. 353, Fig. 354 giving the section from the soil pipe in the N.W. corner, past manholes Nos. 1, 2 and 3, on to No. 4. Fig. 355 gives a section of the line running from N. to S., from the R.W. pipe to manhole No. 3, and Fig. 356 that from the vent pipe on the N. eastward and southward past manholes Nos. 6 and 7 to No. 4. These three sections form only part of the set which would have to be prepared for this case, but they serve as examples, and there is no advantage in repetition. The levels should be taken in



352

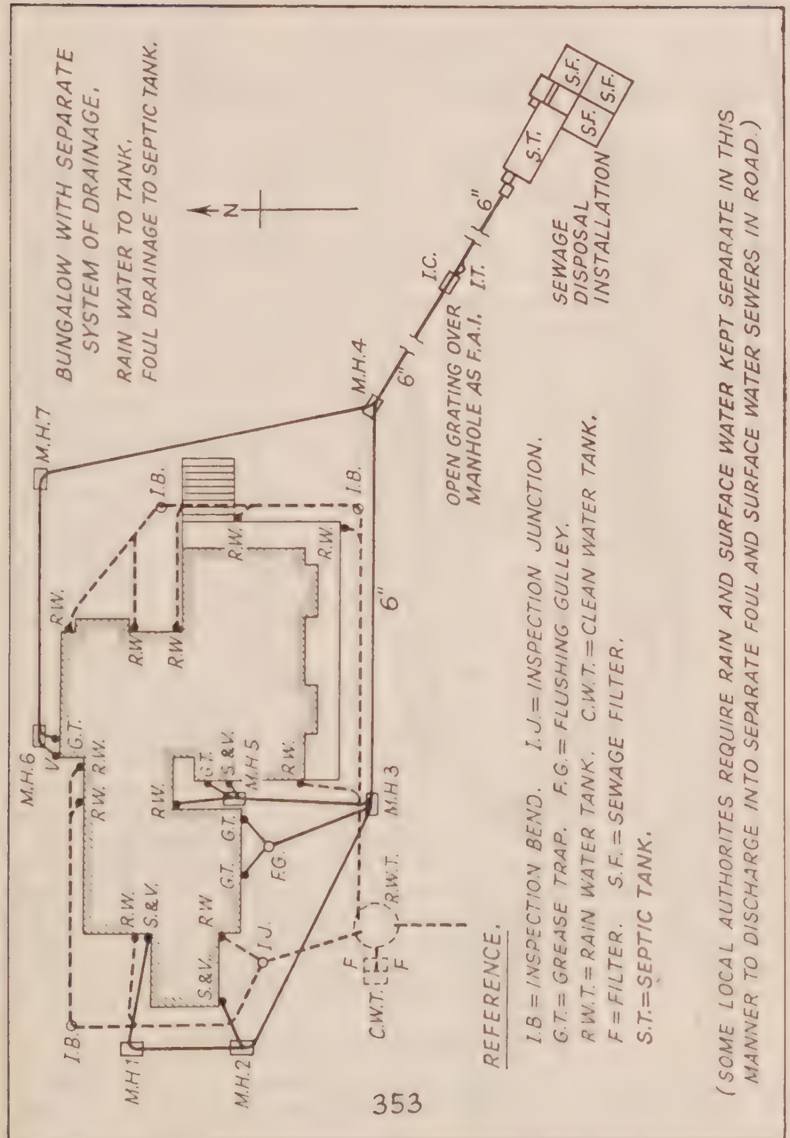
EXAMPLE OF DRAINAGE FOR DETACHED HOUSE.
(IF LOCAL BY-LAWS FORBID INTERCEPTING TRAP AND F.A.I. THEY WILL BE OMITTED.)

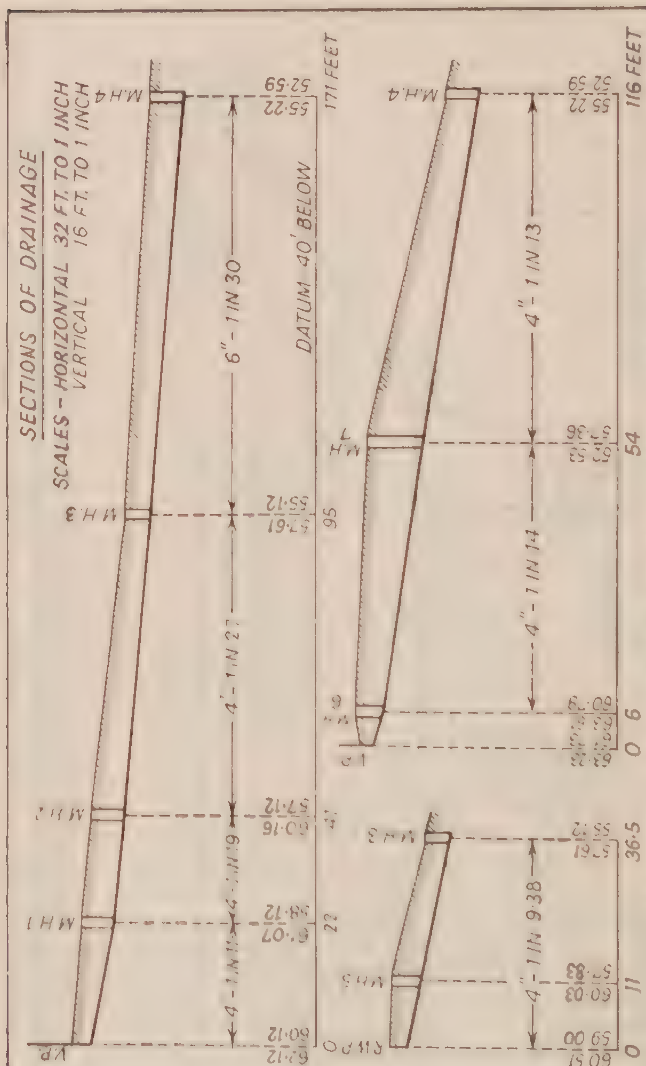
reference to some clearly defined bench-mark, the position and level of which should be shown on the sheet of sections.

Use of Ramps. It will be seen that against each ordinate on the sections two heights are figured, the greater reading being of course the existing surface level, and the less the level of the invert of the proposed drain at that point. (*Note.* The "invert" of a drain is the lowest point of its interior.) The upper end of the drain should be shown about 2 feet below the surface, and the line of drain drawn in such a position as will give a reasonable gradient, without coming nearer to the surface than about 2 feet. The fall shown in the case of Fig. 356 is perhaps excessive, and it might be better to adopt the section shown in Fig. 357, which introduces what is termed a ramp or drop pipe, in order to give a more reasonable gradient. The ramp is shown adjacent to the manhole at R, the drain being continued into the manhole to provide means of inspection and cleansing. The ramp is preferably encased in concrete. The detail of such a ramp or drop pipe is shown in Fig. 358. A stopper is sometimes placed at SS (the rodding eye), but better drain ventilation is obtained without it. If the ramp is not more than about 18 inches in depth, it can be formed in the channelled floor of the manhole.

Arrangements of this sort are sometimes described as "tumbling bays" or "drop manholes", and they may be used, with small modifications, to connect a branch drain at a higher level to a main drain or private sewer at a lower level. The B.S. Code of Practice on Building Drainage shows a preference for a vertical drop pipe to connect the two levels instead of the sloping ramp, and in this case it is wise to carry the drop pipe up to the surface and provide a hinged access cover in case the lower section should get blocked.

Position of Sanitary Fittings. Before leaving this question of plans and sections, it may be pointed out that before the ground plan of any building is inked in by the draughtsman, the position of all the sanitary fittings, their waste pipes and the drains to which they are connected should be finally determined. This can only be done successfully by a careful study of the proposed elevation, so as to select such a position for the soil, waste and vent pipes as will allow them to be carried down without unnecessary bends. This point may appear of minor importance compared with the *tout ensemble* of the elevation, but whatever effect the elevation may have on the beholder, it can have none upon the health of the occupants of the house, and a badly arranged waste pipe may.


BUNGALOW WITH SEPARATE SYSTEM OF DRAINAGE.
RAIN WATER TO TANK.
FOUL DRAINAGE TO SEPTIC TANK.
N
M.H.7
M.H.6
M.H.5
M.H.4
M.H.3
M.H.2
M.H.1
I.B.
R.W.
G.T.
S.&V.
F.G.
I.J.
R.W.T.
C.W.T.
F
6"
I.C.
I.T.
S.T.
S.F.
OPEN GRATING OVER MANHOLE AS F.A.I.
SEWAGE DISPOSAL INSTALLATION
REFERENCE.
I.B = INSPECTION BEND. I.J. = INSPECTION JUNCTION.
G.T. = GREASE TRAP. F.G. = FLUSHING GULLEY.
R.W.T. = RAIN WATER TANK. C.W.T. = CLEAN WATER TANK.
F = FILTER. S.F. = SEWAGE FILTER.
S.T. = SEPTIC TANK.
(SOME LOCAL AUTHORITIES REQUIRE RAIN AND SURFACE WATER KEPT SEPARATE IN THIS MANNER TO DISCHARGE INTO SEPARATE FOUL AND SURFACE WATER SEWERS IN ROAD.)
353



354-356

EXAMPLES OF SECTIONS FOR BUNGALOW DRAINAGE.

(NOTE - IT IS WISE TO USE BLACK FOR NATURAL SURFACE AND FIGURES REFERRING THERETO AND TO KEEP RED, BLUE, ETC. FOR FOUL DRAINS, SURFACE WATER DRAINS AND THE LIKE, WITH REFERENCES AND FIGURES TO CORRESPOND)

Setting Out Drains. Having prepared the plan and sections, we may proceed with the setting out. The lines of the main drain and branches should be first of all pegged out on the ground before any excavation is commenced. The next point is the setting out of the gradients.

Sight Rails and Boning Rods. The only accurate method of securing a perfectly regular gradient is by the sight-rail and boning-rod system. On either side of the proposed drain, at the upper and lower end of each length of drain, a drain pipe of good diameter, say 9 inches, is set up as shown at D.P. in Fig. 359. In each of these an upright post is planted, being well packed round with earth or sand. Sight rails, S.R., are then fixed to the posts at each end of the length of drain, at such a height that their upper edges will set out in the air an imaginary line parallel to the intended drain, and at a convenient height above ground for a man to sight. Sight rails are always fixed first at the point at which the drain commences, which will be the lower end, since it is the outfall level which is usually more or less rigidly fixed by circumstances, such as the level of an existing sewer, and because drains are invariably laid uphill; next, at all changes of direction or gradient, at any convenient intermediate point when desired, and finally at the top end of the drain. The posts should be well away from the edge of the trench to prevent disturbance by falling earth. The sight rail is an ordinary wooden straight-edge, fixed level from one post to the other.

The Boning Rod or Traveller. Fig. 360 shows the elevation and a side view of an adjustable boning-rod, or traveller. It is really an elongated T-square, having the blade in two pieces, and capable of adjustment to any desired length by means of iron bands and clamping screws at S. S. At the foot is an iron shoe, projecting so as to enable it to be rested on the invert of the pipe.

Levelling Calculations. The method of fixing the sight rails at the correct height can be explained by the aid of Fig. 361. It is assumed here that a drain 160 feet long has to be set out at a gradient of 1 in 60 from a length of drain, already laid, whose invert level is 24·75 feet above datum. At a gradient of 1 in 60 the rise in 160 feet will be $\frac{160}{60} = 2{\cdot}66$ feet, so that the level of the invert at the upper end of this length of drain will have to be

$$24{\cdot}75 + 2{\cdot}66 = 27{\cdot}41,$$

as figured in the illustration. Two sight rails are shown in the section, and the level should be set up midway between them to eliminate any error of collimation in the instrument.

The levels figured on the section (Fig. 361) show that the depth of the invert of the drain below ground at the lower end of this length is 31·20 — 24·75 = 6·45 feet, whilst at the upper end it is 32·41 — 27·41 = 5·00 feet. If then we put the sight rails 10·50 feet above the invert of the drain the height of the sight rails above the ground will be 10·50 — 6·45 = 4·05 feet at one end, and 10·50 — 5·00 = 5·50 feet at the other end. This will be a convenient height for sighting in the manner which will be described later. It should be noted at this point that the ground level is of interest only for this purpose, of finding out what will be a convenient height for the sight rails above the drain. Having selected this height the "ground" levels are disregarded in what follows, as such levels are likely to be changed slightly, by falling in of stones, or by earth thrown up, and are therefore quite unreliable as a basis from which to set out the levels of the drain.

Use of Surveyor's Level. In the present instance, having decided that the sight rails are to be 10·50 feet above the drain, they must be set up at reduced levels of 24·75 + 10·50 = 35·25 feet at the lower end, and 27·41 + 10·50 = 37·91 feet at the other end. Suppose that when the level has been set up properly as shown, we find on sighting upon a bench mark, or other point whose level has previously been determined, that the height of the line of collimation of the telescope is 40·53. Then the sight rail at the lower end must be set up, quite level, so that a staff held on its upper edge reads 40·53 — 35·25 = 5·28 feet, while at the upper end of the drain the sight rail must be fixed so that a staff held on it reads 40·53 — 37·91 = 2·62 feet. The boning rod is then adjusted, by its clamping screws, so that its length is exactly 10·50 feet.

Adjustment for Line and Gradient. For the purpose of laying the pipes to the exact line, the centre of the trench should be marked on each sight rail, and a plumb-bob suspended from this point by a fairly stout cord. Each pipe must be firmly bedded in the line joining these cords, its exact level being secured by the pipe layer inserting the shoe of the boning-rod upon the invert of the pipe and keeping the rod upright. The overlooker then applies his eye to the lower sight rail to see whether the top edge of the cross head of the boning-rod is above or below the line of sight from rail to rail. If it is above, the ground must be trimmed away and the pipe lowered until the true grade is reached. Should it be below, it should be gently raised and packed with concrete.

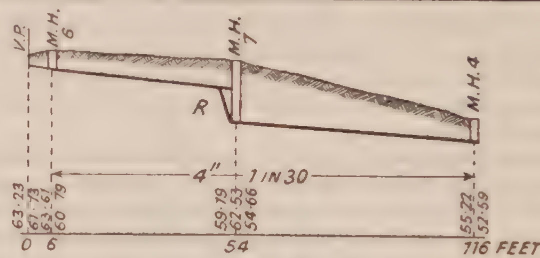
The trench should not be cut wider than is necessary to allow sufficient room for the pipe layer to work at the bottom. The length opened up at one time must be governed by the number of

men at work, the nature of the ground and the interference with access to the premises. Where the ground is bad from wet sand or other causes, or in passing close to walls and buildings, where the foundations may be liable to disturbance by reason of the trench being kept open, it should only be cut in short lengths and with especial care.

Timbering Trenches. As the excavation of the trench proceeds, the sides should, unless the soil is very firm and the depth of the drain small, be supported by proper timbering, fixed by competent timber men. A method applicable to ordinary cases of moderately firm earth is to place vertical boards about 9 inches by $1\frac{1}{2}$ inches in section, termed poling boards, at frequent intervals, or close together, according to the nature of the ground, supported by horizontal timbers about 9 inches by 3 in section, termed walings. The walings are kept apart by struts, about 4 inches square, wedged tightly between them. The struts should not be nearer together than about 6 feet, or they will interfere with the work of the pipe layer too much. In the method described the timbering cannot be placed in position until the ground has been excavated to the depth of the poling boards; if the ground is too loose for this to be done safely, it is necessary to increase the thickness of the boards to 2 inches and to point their feet, so that they may be gradually driven down as the excavation proceeds. Boards driven in this way are usually called "runners". In a very deep trench, the method of timbering is best carried out on the lines shown in Fig. 362, in which two settings of runners are pointed at the foot and driven in. If the ground is very bad, the walings can be omitted, the trench being timbered by means of horizontal planks or sheeting, placed close together, secured by vertical polings about 9 inches by 3 in section, and about 6 feet apart, secured by strong struts as before described. Where the ground is very bad too, it may be advisable to leave the lower timbering in permanently.

"Grips" or Handlocks for Making Drain Joints. If the bed of the trench is of good firm earth, and the local by-laws do not require a concrete bed to be used, the pipes can be firmly bedded throughout their length by forming grips or sinkings under each socket, as in Fig. 363. This gives a firm bed to the pipe, and enables the pipe layer to get his hand under the socket to make the joint, but the work has to be done entirely by "feel", it being impossible to see the joint underneath the pipe.

Concrete Under Pipes. When the ground is not very good, and in any case if the local by-laws require it, the pipes should be laid on a bed of concrete, at least equal to the diameter of the pipes



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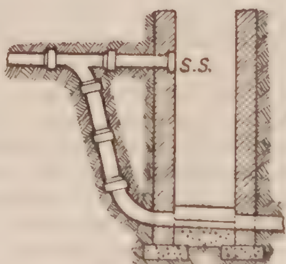
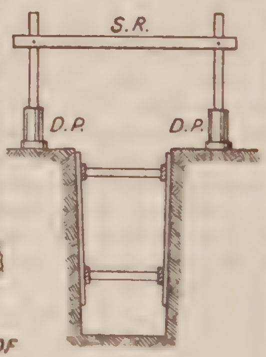


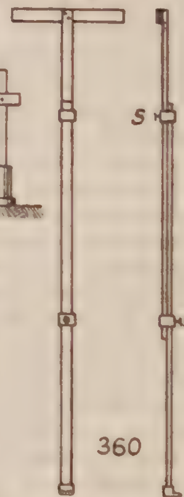
358

357 & 358 SHOW ONE FORM OF RAMP TO REDUCE EXCESSIVE VELOCITY IN DRAINS OF STEEPLY SLOPING SITES



359

SIGHT RAILS AND BONING RODS



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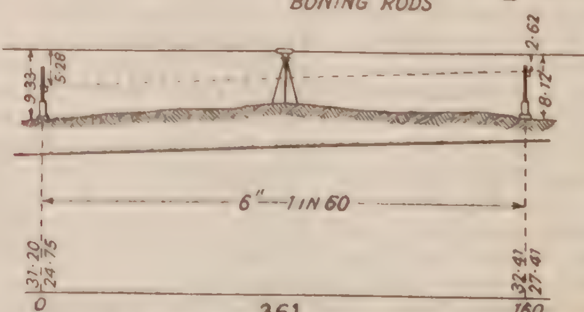


361

EXAMPLE TO SHOW USE OF SURVEYORS LEVEL TO SET UP SIGHT RAILS TO GIVE CORRECT GRADIENT

or of such thickness as the local by-laws direct. This is known as "bedding" the pipes. The by-laws may require "haunching", in which case the concrete is added to and sloped off to form the section shown in Fig. 364. Under buildings; under drives or tracks likely to be traversed by heavy lorries; or where the drains must be less than 18 inches deep, the drain, if of stoneware, should be "surrounded" with concrete, as explained in Chapter IX.

When concrete is to be used as either "bedding", "haunching" or "surrounding", it may be preferred to lay the first 3 inches of concrete in the bottom of the trench, and to lay the pipes on bricks, placed one behind each socket, with a pat of stiff mortar between the brick and the pipe. This gives ample room for making and inspecting the joints, and saves the time and trouble needed in cutting "grips" in the concrete under each joint. This method should be permitted only if the space under the pipes and between the bricks is now packed in with fine concrete so that the requisite depth of concrete foundation is completed and a complete support provided for the whole pipe-line.

The bricks are subsequently completely concreted in and then left as a "bedding" or added to, to provide "haunching" or "surrounding" as the needs of the case or the local by-laws may require.

Bad Ground. Where the ground is exceptionally bad and wet, mere concrete alone is sometimes not sufficient support. The usual method of procedure in such a case is to drive in timber piles at intervals along the sides of the trench, connect them by pieces of timber spanning the trench, and lay a foundation of elm planks from one to the other to carry the concrete. An alternative method would be to reinforce the concrete, by embedding in it steel-mesh reinforcement. If the nature of the sewage permits the use of iron pipes, they provide the best way out of the difficulty. Timber piles, about 6 inches square, can be driven in at a distance apart equal to the outside diameter of the pipe and the pipe can be supported on cross pieces, as shown in Fig. 365.

Use of Badger. We may now revert to the case of the stoneware drain laid under ordinary conditions. As each pipe is jointed, a "badger" should be drawn through, in order to remove any mortar which may have found its way through the joint. In its ordinary form, a badger consists of a semi-circular piece of wood having, preferably, a rubber ring projecting from its curved edge. A handle about 3 feet long completes its construction. An improved form of this appliance is shown in Fig. 366 consisting of two circular discs of wood, edged with rubber bands and connected

by a steel spiral spring, which enables the badger to be drawn through a bend.

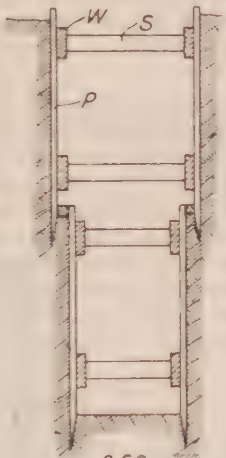
Testing New Drains. The drain having been laid and jointed, it should next be inspected and tested by the surveyor. He should walk along the trench, inspecting both pipes and joints, marking any defects with chalk as he goes. After the work has been completed not less than twenty-four hours, he should apply the water test, in order to determine the water-tightness of the drain. The method of doing this will be fully dealt with under the heading of sanitary surveys.

Filling in Trenches. If found all in order the trench can be filled in. This is a matter requiring careful supervision, as damage is easily done by falling stones or brickbats. For the first foot of depth over the pipes, the earth should be freed from stones; after depositing it in the trench it should be well but carefully rammed or consolidated. The filling in should be completed in layers of not more than 1 foot in depth, each layer being well rammed. On completion, the drain should be again tested in order to detect any damage during the filling in. It is a good plan to make the contractor responsible for the drain standing the water test three months after completion, in order to ensure the use of cement in proper condition and of good quality.

Connection to Sewer. The connection to the sewer is a matter calling for mention. In developing an estate, junctions are often put in the sewer opposite the various plots. The mouth of the branch of the junction is sometimes closed by means of a piece of slate, but this is a slipshod and unsatisfactory practice. Proper junctions, sometimes called "joinders", can be obtained for the purpose, having the branch temporarily but securely closed, as shown in Fig. 367. In this example a cap is formed as part of the junction, a fairly deep triangular groove being formed round it. A few taps with a cold chisel readily detaches it, leaving the socket free for the connection of the drain.

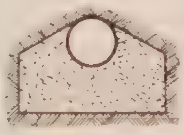
If a junction has not been put in, it is a frequent practice to remove two or three pipes in order to build one in. This can be obviated by the use of the special junction shown in Figs. 368–369.

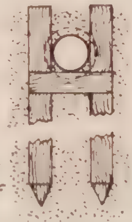
One pipe only need be removed. From the plan given in Fig. 368 it will be seen that the junction has a very long socket, but, as shown in side elevation, Fig. 369, this socket is only applied to the lower half of the pipe. After the junction has been jointed to the two pipes A and B, the open space at S, due to the presence of only a half-socket, is closed by a short piece of pipe having a double socket on its upper half only, as shown in section in Fig. 370.

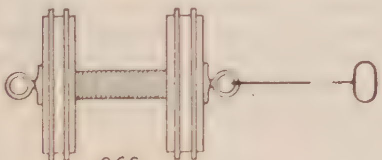


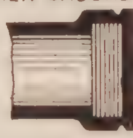
362
TIMBERING FOR DEEP TRENCHES IN SOFT GROUND

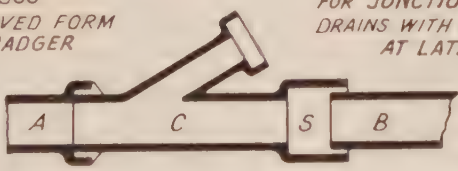

363
'GRIPS' OR HOLLOWS IN BOTTOM OF TRENCH OR CONCRETE, TO PROVIDE ROOM FOR MAKING THE JOINTS


364
CONCRETE FOUNDATION HAUNCHED UP TO TOP OF DRAIN


365
TIMBER SUPPORTS LEFT IN, WHEN FILLING IN, WHEN GROUND IS BAD


366
IMPROVED FORM OF BADGER


367
SEALED SOCKET OR 'JOINDER' FOR JUNCTION OF BRANCH DRAINS WITH SERVICE SEWER AT LATER DATE



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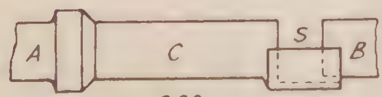

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370

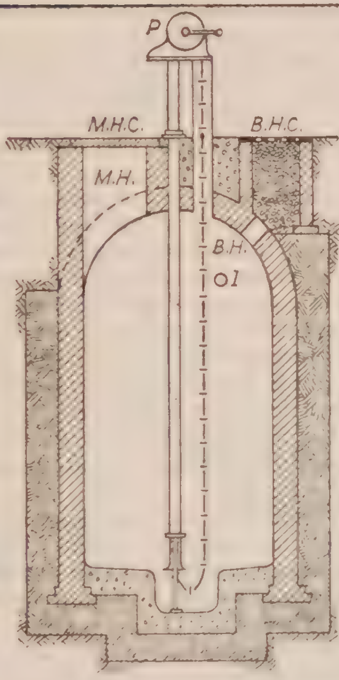
368–370 SHOW A SPECIAL JUNCTION PIPE TO CONNECT DRAIN TO SEWER WHEN NO PROVISION HAS BEEN MADE

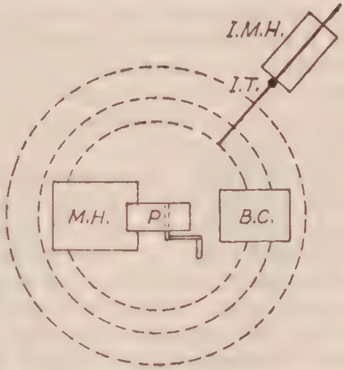
Cesspools. In the case of country districts there may be no sewer, and the house may not be of sufficient size to justify the installation of a sewage-disposal installation of its own. Recourse must then be had to a cesspool.

The usual official requirements as to cesspools are: It shall (1) be not less than 50 feet from a dwelling; (2) be not less than 60 feet from any well, spring, or other source of water supply; (3) be readily accessible for cleansing, and in such a position as will obviate the contents being carried through a building; (4) have no connection with a sewer or watercourse; (5) be disconnected from the drain by means of an intercepting trap; (6) be of brickwork built in cement mortar on a bed of concrete, cement rendered or asphalted inside, and backed with not less than 9 inches of clay puddle if the soil is waterlogged; (7) be covered, ventilated, and have means of access.

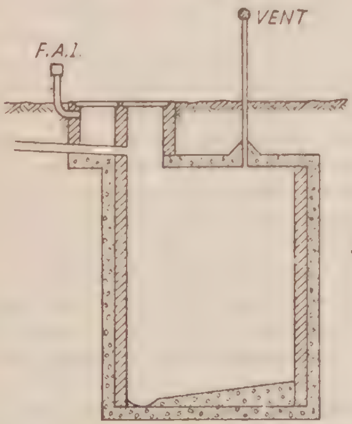
Cesspools may be either rectangular or circular on plan and a very usual rule for size is to allow 1 cubic foot per day for say 100 days for each person expected to be in occupation. This is not a generous allowance, and it is assumed that bath and basin water will be led to a soak-away and that all rainwater will be excluded.

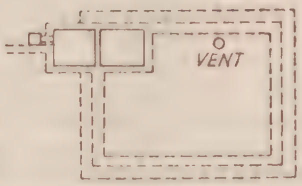
Fig. 371 shows a section through a good type of cesspool for houses in remote districts where there is no public cesspool emptying service. It is of circular plan and domed over, built of brickwork, cement rendered, and backed by clay puddle; the floor is of concrete, falling to a sump or sinking in the middle, and with a foot of clay puddle below it as an alternative to concrete. It has an access shaft covered by a stone slab or manhole cover at M.H.C. It is ventilated by forming a breathing chamber having a grating over it at B.H.C. This is about 18 inches square on plan, and is constructed as follows: A short length of 9-inch pipe is built into the dome to form a breathing hole, B.H. Over this is placed a galvanised iron grating. The chamber is then filled with broken stone, such as road metal, and completed by a grating. The inlet is at I. In some cases it is desired to utilise the sewage for the kitchen garden, and this is best accomplished by the provision of a chain pump, such as shown in the figure at P. The essential part consists of the pump tube and an endless chain carrying circular iron discs at intervals of about 9 inches. These discs carry the sewage up the pipe when the handle is turned and discharge it from the mouth of the pump. The figure shows a plan of the ground above the cesspool, and gives the relative positions of the parts. It will be seen that an intercepting chamber is provided close to the cesspool. If some distance from any





371. PLAN AND SECTION OF CIRCULAR CESSPOOL, WITH CHAIN PUMP, SUITABLE FOR REMOTE DISTRICT WHERE NO PUBLIC EMPTYING SYSTEM EXISTS AND HOUSEHOLDER HAS TO DISPOSE OF CONTENTS BY SPREADING OVER OWN OR NEIGHBOURING FARM LAND AND PLOUGHING IN.





372. PLAN AND SECTION OF RECTANGULAR CESSPOOL, WITH SUMP AND MANHOLE COVER, SUITABLE FOR DISTRICT WHERE LOCAL AUTHORITY EMPTIES AT REGULAR INTERVALS BY CESSPOOL EMPTYING TANKER WITH MOTOR PUMP AND ARMOURED HOSE.

building, the cover of the intercepting chamber can be in the form of a grating, to act as a fresh-air inlet to the drains.

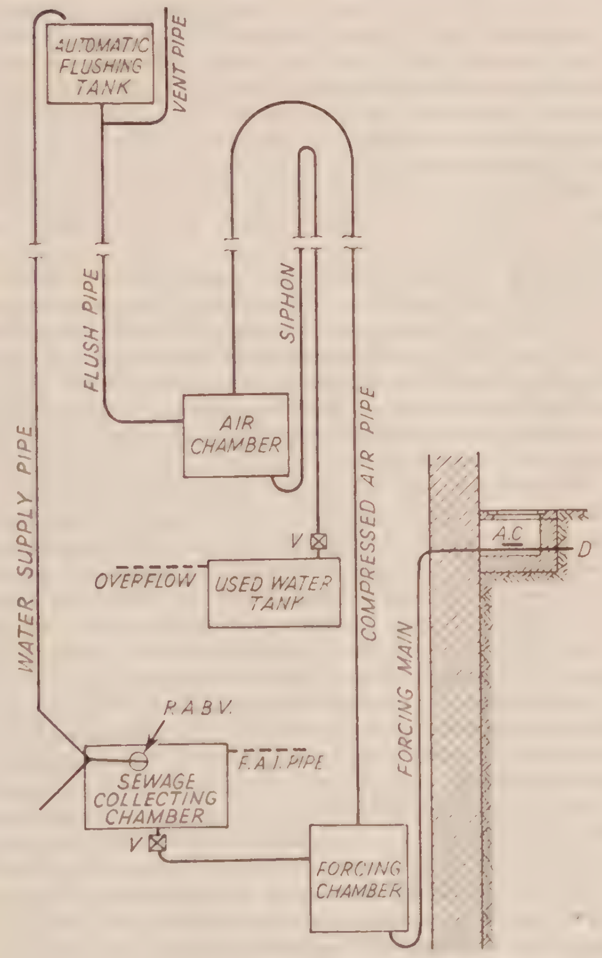
If the local authority undertakes to empty the cesspool at regular intervals by means of a motor tanker provided with a suction pump and several lengths of armoured hose, the chain pump illustrated can be omitted, and the form shown in Fig. 372 may be found preferable.

Sewage Lifts. It is sometimes necessary to adopt means for lifting sewage from a drain to a sewer, as where a building has a deep basement. Pumps of small capacity, even though of the centrifugal type, are liable to become choked by the solid matter in the sewage, and lifting by means of compressed air will usually be preferable. The two types of apparatus most used are the Sewage Lift and the Ejector. The former will be preferred on small schemes where there is an ample water supply at good pressure, the latter where there is electric power available.

The arrangement of the parts of the Sewage Lift is shown diagrammatically in Fig. 373. It is worked by means of an automatic flushing tank and the principle is very simple.

The flushing tank is placed fairly high up in the building, and the other chambers in approximately the positions shown. The drains discharge into a sewage-collecting chamber, from which the sewage flows to the forcing chamber, being prevented from returning by a non-return valve. When the sewage reaches a certain level in the collecting chamber, it opens the reverse action ball valve, R.A.B.V., and allows the automatic flushing tank to fill. The latter in due course discharges, expelling and compressing the air in the air chamber, which exerts a pressure on the sewage in the forcing chamber and drives it up through the forcing main to the high level drain, D. The capacity of the automatic flushing tank is greater than that of the air chamber; sufficiently so to enable the water not only to fill the latter, but also to charge the siphon and so empty the water, after it has done its work, into the used water tank, from which it can be utilised for any other than domestic purposes, such, for example, as drain flushing. After the air chamber has been emptied of water in this way, it is re-charged with air from the vent pipe connected to the flush pipe, which is now empty. The sewage-collecting chamber is provided with a fresh-air inlet pipe, communicating with the outside air. An inspection chamber is provided just outside the building, with an access cap, A.C.

The Shone Sewage Ejector. The Shone ejector is similar only in the sense that it is operated by compressed air. The compressed



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SEWAGE LIFT OPERATED BY MAIN WATER SUPPLY. FOR USE IN BUILDING TOO LOW TO DISCHARGE INTO SEWER BY GRAVITY

air is, however, derived from an air-compressing plant. The system is applicable not only to the drainage of deep basements, but also to the sewerage of low-lying districts. The ejector can be adopted for the raising of water, sewage or sewage sludge, and is usually installed in a brick chamber. The apparatus can be made of any size or shape convenient for the special conditions for which it is required. The air compressor will usually be driven by an electric motor, which arrangement enables the rate of working to be automatically regulated. In exceptional cases, where electric power is not available, an oil engine may be used.

The Working of the Ejector. A diagrammatic section of an ejector is given in Fig. 374. The action of the apparatus is as follows: The sewage gravitates through the inlet pipe into the ejector and gradually rises therein until it reaches the underside of the bell B. The air at atmospheric pressure inside this bell is then enclosed and the sewage, continuing to rise outside and above the rim of the bell, compresses the enclosed air sufficiently to lift the bell, spindle, etc., which opens the compressed air admission valve, C.A.V. The compressed air, thus automatically admitted into the ejector, presses on the surface of the sewage, driving the whole of the contents before it, through the bell-mouthed opening at the bottom, and through the outlet pipe, to the high-level gravitating drain. The sewage can only escape from the ejector by the outlet pipe, as the instant the air pressure is admitted on to the surface of the liquid, the valve on the inlet pipe falls on its seat and prevents escape in that direction. The sewage passes out of the ejector until its level therein reaches the cup, C, and still continuing to fall, leaves the cup full, until the weight of the liquid in the portion of the cup thus exposed, and unsupported by the surrounding liquid, is sufficient to pull down the bell and spindle, thereby reversing the compressed air admission valve, which first cuts off the compressed air and then allows the air within the ejector to exhaust down to atmospheric pressure. The outlet valve then falls on its seat, retaining the liquid in the outlet pipe, and the sewage flows into the ejector once more, driving the free air before it through an air valve as the sewage rises; and so the action goes on as long as there is sewage to flow.

The positions of the cup and bell floats are so adjusted that the compressed air is not admitted to the ejector until it is full of sewage, and the air is not allowed to exhaust until the ejector is emptied down to the discharge level. This method of draining basements has been very extensively adopted in the United States.

particularly in Chicago, where the basements are, in many cases, of very considerable depth.

Stable Drainage. The general practice in draining stables is now very different from what it used to be, it being recognised that openings to a drain, inside a stable building, are as likely to be injurious to horses as they are to human beings in a domestic building. The floor should be of hard, non-absorbent material, such as Staffordshire blue bricks, adamantine clinkers, or granolithic concrete. The stable should be drained by laying the paving so that the floor falls to shallow surface channels, connected to a main channel leading to a gully outside the building.

In a large stable, the main channel should be of iron, and covered with a grating, as shown in section in Fig. 375. The channel and grating should, of course, be protected against corrosion. The form of gully used for stable work should be different from that of the ordinary yard gully. It should have a perforated iron bucket to intercept particles of straw, horse dung, etc. The bucket is readily removable, like the tray of a grease trap. Such a gully is shown in section in Fig. 376. It would have the usual iron grating over. In other respects the drainage of a stable follows the general principles already given for domestic work.

Petrol Interceptors. In the case of a garage a difficulty occurs that has not occurred in the cases already dealt with; that of the danger of petrol washings finding their way into the drainage system and possibly leading to explosions. By the Public Health Act, 1936, it is illegal to discharge into a sewer any petrol, or any other oil which gives off an inflammable vapour at a temperature of less than 73° F. In a small garage, attached to a building having a fair amount of land, the best thing to do is to lead the surface drainage of the garage to a soak-away pit, dug well away from the building, but in the case of a garage in a crowded district this is difficult if not impossible.

The requirements of the London County Council may be given as an example of what should be done in other cases. Figs. 377 and 378 show a section and plan of a special form of interceptor which they will accept as meeting the case, the example given being suitable for a garage taking six cars. It will be seen to consist of three chambers, each 3 feet square and 4½ feet deep, built of brickwork on a concrete floor.

Calling the chambers Nos. 1, 2 and 3, the only exit from No. 1 to No. 2 is through a pipe submerged to 12 inches from the floor, the pipe thus being far enough from the floor to avoid sludge passing. The only exit from No. 2 to No. 3 is by a pipe submerged

to 6 inches from the floor, while a similar pipe forms the outlet from chamber No. 3 to the drain. By this arrangement the petrol is left to accumulate at the top of the sewage in each chamber, any vapour being carried off by the ventilating pipes shown by dotted lines. Probably other means could be devised to get over this difficulty, but the example given shows what is at present required for London garages.

Drain Repairs. In concluding this section a few words may be added on the repair of drains and on the remodelling of old drainage systems. In the ordinary way, on finding that a drain is leaky, one opens up the ground in order to expose the drain and so trace the leaky joints or cracked pipes. This necessitates the ground remaining open for at least a day or two, and often means taking up floors and so on.

A system of repair has been in use for many years by a London company, based on the following lines: The drain is first cleaned out and disinfected, the disinfectant being applied under pressure, so that it will pass through any defects and so disinfect the surrounding soil. An appliance is then passed through the drain, charged with Portland cement grout, which, by means of compression, is forced into every flaw in either pipes or joints. The inside of the drain is said to be left free from any roughness due to this process, and the company is said to guarantee the drains to stand the water test on completion. The system has much to commend it where a drain is only slightly leaky, and the covering of the ground is a matter of great inconvenience, but it would be an inadequate means of dealing with a very bad case.

Remodelling Old Drains. The remodelling of old drainage systems is not a matter calling for a very extended notice. The principles which a new system should satisfy have been fully laid down in the preceding chapter, but it should be pointed out also that where, in remodelling a system, an old drain is discarded, the drain should be taken up and the trench disinfected before returning the earth. The extent to which an existing system is remodelled is a matter dependent entirely on the circumstances of each individual case. In some cases, sound but moderate proposals would be certain to be carried out, and sanitary progress thereby furthered, while an elaborate proposal might lead to nothing much being done, and progress thereby retarded.

Drain Rods and Fittings. For the cleansing of drains and the removal of stoppages, various tools are used, fixed to drain rods. The latter are of red malacca cane or of spiral and flexible steel spring, the usual length of each section being 3 feet with a total

length in the complete set or bundle of anything from 30 to 90 or 100 feet. The rods are fitted with screws and sockets, so that they may be put together to form a long rod. Various tools are used for fixing to the end of the rod, including fixed and hinged badgers, double "corkscrews", spring hooks, etc., for the purpose of removing obstructions.

After the removal, the drain can be finally swept out by a circular brush of either bass or whalebone, affixed to the end of the rods.

CHAPTER XI

SEWERAGE

"Sewerage" and "Sewage" Defined. By sewerage we mean the system of sewers for the drainage of a district, including not only the wastes from the various sanitary fittings, but also the rainwater which falls on the area sewered and is not absorbed by the ground. The dirty water carried by the sewer is "sewage".

Early History of Sewerage. Little is known as to the early history of sewerage in Britain, but that sewers are of ancient origin is established by the fact that some of the main sewers constructed by the Romans can still be seen in Rome.

Layout. In designing a system of sewerage the engineer must have regard to the position of the outfall for the discharge of sewage, the pattern of the streets on plan, the area of the land to be drained, its possible population, the nature of the surface soil, the configuration of the ground, the rainfall and the water supply. Students and others who need a deeper knowledge of detail should study the British Standard Codes of Practice on Building Drainage (C.P. 301) and Civil Engineering Code of Practice (No. 5) on Sewerage.

Position of the Outfall. The position of the outfall will, of course, be the site chosen for the purification processes. The site should preferably be at a low level, so that the discharge to it may be by gravitation and the cost of pumping may be avoided, whilst land of low value would naturally be preferred, removed from habitations so that nuisance may not be occasioned, and ample in extent to provide for possible future extensions. These considerations may, of course, conflict with one another; for instance, it is possible that the low-lying land to which a gravitational discharge is practicable may have a high value for industrial purposes, in which case a careful comparison would have to be made between the economy of utilising such a site, or of using some other site in an unobtrusive position, of less value, to which the sewage would have to be pumped.

Outfall and Tributary Sewers. Working backwards from the outfall, the main outfall sewer will rise at a small gradient and branch off into different districts by smaller sewers, which will receive tributary sewers serving particular streets or estates and

many of these will, in turn, receive tributary sewers from other streets. The plan form of the complete sewerage scheme will therefore depend upon the lay-out of the town and upon the estate planning.

Size of Sewers. The diameter required for any particular sewer will depend upon:

1. The area of the district to be drained by that sewer, chiefly because the amount of storm water to be carried off will depend largely on this. The maximum rate of run-off will, however, not be *proportional* to that area, because in a large area the flow will be spread over a longer period of time, as will be explained later.

2. The density of population: firstly, because the discharge of foul sewage will depend upon this, and secondly, because the more dense the population the greater will be the proportion of impermeable surfaces, in the way of streets, roofs and paved yards, and therefore the larger will be the run-off of storm water to the sewers. In reckoning density one should not have regard merely to the present population, but rather to the population which may be expected when the land is fully developed, or that is likely during the next 30 years or so. It is not an expensive matter to make a sewer a little larger than is needed for present requirements, but it is very costly to take up one sewer and replace it by a larger one. In most cases the density provisions of a town-planning scheme will be of very great assistance in estimating future population and the likely area of roofs and paved surfaces.

3. The nature of the surface soil and its degree of cultivation: some soils are more permeable than others and water falling upon them will percolate down to form underground streams. Even on relatively impermeable surfaces, if not paved, much of the storm water will run into ditches and streams and will not enter the sewers.

4. The physical features of the land. Other things being equal, water will percolate into steep land to a less degree than into flat land, because it will have less time to soak in. Also, since on steep land the water will travel at a greater velocity, the flow from distant parts of the drainage area will not lag much behind that from the nearer parts, so that the run-off will be more concentrated.

5. The amount of rainfall in the district. The mean annual rainfall is, however, of less importance than might at first be supposed, because in the design of a sewerage system we are not concerned with the total flow in a year, but with the magnitude of short storms, and it is by no means always the case that districts subject to the heaviest annual rainfalls are subject to the heaviest storms.

6. The water supply of the district, since all the water which goes into a house will normally come out again as sewage. We should, however, not ignore the fact that the water supply per head of population tends to increase, in some districts because of the growth of the number of motor cars and consequently of water used in washing them, and in other districts through the more universal provision of baths and water closets. In our estimate of the water supply we should include water (if any) coming from other sources than the town mains; for example, from private wells, springs and rainwater tanks. In some places, even where there are water closets, the use of cesspools may be general, in which case some of the water supplied to the houses will not be discharged into the sewers; cesspools, however, must be regarded as a temporary expedient, likely to be dispensed with when the sewerage system becomes available, so that the sewers should be made large enough to accommodate the sewage which is, for the time being, discharged into cesspools.

7. The gradient available for the sewer. It is obvious that the velocity will be increased by an increase in the gradient, so that a smaller cross-sectional area is needed to obtain the same discharge.

At a later stage in this chapter we shall return to this subject of the determination of the diameter required for a sewer.

Combined, Separate and Partially Separate Systems. There are three methods of arranging a system of sewers, known respectively as the combined, separate and partially separate systems.

Combined System. The combined system involves the provision of a single sewer in each street, there being also a single system of drains to each building. The one sewer therefore takes all the domestic sewage, rainwater on roofs and backyards, and the road drainage.

Separate System. In the separate system there are two sewers, one for foul sewage and one for surface water; similarly, each house has two sets of drains, one for sewage and one for rainwater.

Partially Separate System. The partially separate system is a compromise between the two just described, and consists of two sewers, one to take all the drainage from private houses, (i.e. the "soil" sewage, the waste water from baths, basins, scullery sinks and rainwater from roofs and private paved spaces), while the other sewer takes the surface water from road gullies and sometimes the rainwater from the roofs of public buildings and public paved spaces. The rainwater from the roof of private houses is sometimes described as the "unavoidable rainfall". The partially

separate system (like the combined system), involves the house owner in only one set of house drains.

Each of the systems possesses certain advantages and disadvantages when one is compared with the other, but individual preference and local conditions enter largely into the choice of system.

The quantity of rainwater to be dealt with per day is very variable, and it is difficult to design a foul sewer satisfactorily if it is liable to enormous fluctuations of volume of flow. If two sewers are used, the foul sewer can be relatively small, and the smaller a sewer is, so long as it is large enough for its work, the cleaner can it be kept. Again, if pumping has to be resorted to, the quantity to be pumped is reduced to a minimum by the exclusion of rainwater. It is quite unnecessary to incur considerable initial and annual expense in laying down a pumping installation of sufficient capacity to lift all the rainwater, as well as sewage, to a higher level; it is quite reasonable, if proper precautions be taken, to run the surface water to the nearest natural watercourse.

On the other hand, while in rural districts, generally speaking, the rainfall is comparatively pure and so can be safely taken direct to the watercourses, in other cases it is of a very different nature. The first washings of a busy street, after a dry spell, would give a liquid that could only be fairly regarded as foul sewage. Another consideration is that if there are two sewers in the street instead of one, there must be proportionately greater obstruction to traffic by repairs. It has been said that another drawback of the separate system is that there is a possibility of house drains, conveying foul sewage, being connected to the rainwater sewer; but this is hardly a valid argument, as the local authorities have ample powers of supervision.

Service Sewers. The reason that the separate system has not been extensively adopted is that, generally speaking, the local authorities have no power to compel the provision of two sets of drains to the houses. This fact has led to the fairly extensive adoption of the partially separate system. The sewage from the higher levels of a district is collected into subsidiary sewers of relatively small diameter, say from 9 inches upwards, and is discharged into main sewers at the lower levels.

Intercepting Sewers. Where the levels of the district vary considerably it may be necessary to use intercepting sewers, that is to say, subsidiary main sewers running on different contours and draining the areas above them, all discharging ultimately into the main outfall sewer. It often happens that the sewage from a

low-level intercepting sewer has to be pumped up into the outfall sewer. Assume a town laid out on a hill sloping rapidly down to a river. If there were only one sewer, at the lowest level, it would be liable to be flooded by the surface water from the high levels; further, the sewer might be at such a level that the whole volume of sewage passing through it would have to be pumped up at the outfall. The method then adopted is to have more than one sewer to intercept the drainage above that level. Thus, in Fig. 379, the sewer on contour A would take the drainage from above its level, the sewer on contour B the drainage between the levels A and B, and sewer C the drainage between B and the river. This is the arrangement in London, north of the Thames. The three sewers would then converge at some distance from the town and the whole combined volume would be carried on in the main outfall sewer. Assuming, in Fig. 379, that it is necessary to keep the main outfall sewer at about the level of B, sewer A would discharge into B by gravitation, and the volume passing through C would be pumped up into B.

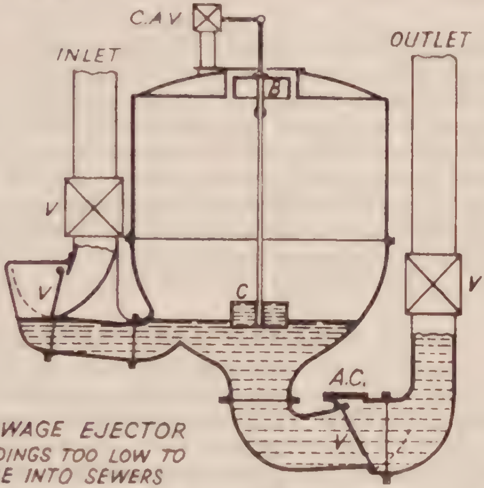
Pipe Sewers. Small sewers are generally constructed of iron pipes with caulked lead joints or of stoneware pipes with cement joints, as in Fig. 302, though very occasionally one of the patent forms shown in Figs. 305–316 may be used.

Stoneware pipes for sewers may be obtained in 3-inch rises up to 30 inches diameter, though the larger sizes are easily damaged in transit and are not very popular.

Iron pipes, on the other hand, are available from 6 inches in the same rises up to 4 feet diameter and larger.

Precast Concrete Sewers. Although these large sizes in cast-iron socketed pipes are available, most engineers choose prefabricated concrete pipes for big intercepting or trunk sewers. They are more costly than stoneware pipes in the small sizes, 12 inches in diameter and smaller, but in the larger sizes (up to 6 feet in diameter) they prove more economical, in addition to having greater strength.

Joints for Pipe and Concrete Sewers. The least satisfactory feature of the concrete tube, as ordinarily made, is the joint, which is illustrated in Fig. 386. It is known as an "ogee" joint and it will be seen that the moulded ends of the pipes are simply put together with a little cement mortar between. A rather better form is that shown in Fig. 381. Concrete tubes are also obtainable with sockets and spigots, and are then jointed with cement mortar in the ordinary way. They are also obtainable with a "self-centring" joint, as illustrated in Fig. 382, the sockets and



SHONE SEWAGE EJECTOR FOR BUILDINGS TOO LOW TO DISCHARGE INTO SEWERS BY GRAVITY

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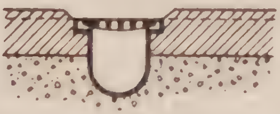

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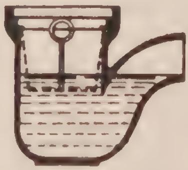
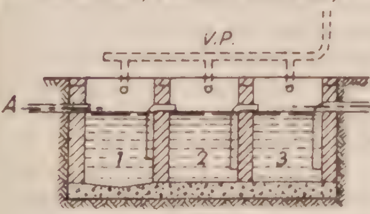
CHANNEL IN FLOOR OF LARGE STABLE, COVERED BY HEAVY GRATING, (GULLEY OUTSIDE)



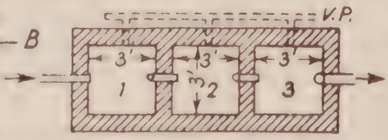
376

BUCKET GULLEY FOR STABLE YARD



SECTION

377



SECTIONAL PLAN A-B

378

PLAN AND SECTION OF PETROL INTERCEPTOR FOR MULTI-CAR GARAGES. (MOST TOWNS WILL ACCEPT AN INTERCEPTOR WITH ONLY 2 CHAMBERS)

spigots being so shaped as to ensure the pipes being perfectly concentric.

Foundations for Sewers. Stoneware pipes and concrete tubes may be supported by concrete, as shown for the drain of Fig. 364. This is essential if the subsoil is soft, as the weight of the sewer is then distributed over a larger area of subsoil; it is also necessary if the subsoil is a hard rock, as this cannot be cut to be smooth enough to give an even bed for the pipes. Also if the sewer is under a carriage-way it is always advisable to support it by concrete in this way, whatever the nature of the subsoil, whilst, if the depth is so slight that the sewer may be damaged by heavy vehicles, the concrete may be extended over the sewer to form a covering arch.

When the diameter of the sewer is greater than the largest size made in iron or stoneware, one has to choose between concrete tubes and sewers built up of brickwork or concrete in situ. The concrete tubes will normally be much cheaper and are much more rapidly laid, which is an important point in view of the inconvenience caused to traffic by sewerage works in streets.

Egg-shaped Sewers. The shape of the cross-section of sewers is usually either circular or egg-shaped. Egg-shaped sewers are not so popular as they once were, as the same capacity in a circular iron sewer is so much stronger. Nevertheless, there are, as will be seen, certain qualities inherent in the egg-shape which are not found in the circular cross-section. Stoneware are usually obtainable only in the circular form, but concrete tubes can be obtained in either shape; brickwork can also be built to either form.

Egg-shaped and Circular Cross-sections Compared. The respective advantages and disadvantages of the two shapes may be briefly stated. The circular sewer of brickwork is stronger than the egg-shaped, and slightly less expensive to construct, but the egg-shaped has some advantage from a hydraulic point of view. Figs 383 and 384 show sections of two sewers, both having the same sectional area and both containing exactly the same quantity of water. It will be seen that the water is of greater depth in the egg-shaped sewer than it is in the circular; the greater the depth of the flowing liquid, the greater its velocity, therefore the egg-shaped sewer will, when compared with one of circular section, equal in area, and containing the same volume of liquid, be the more self-cleansing.

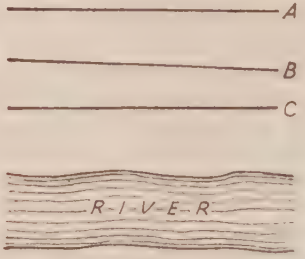
The object to be borne in mind in designing such a sewer is to give it the greatest possible hydraulic mean depth for small volumes of flow, and this condition is fulfilled by egg-shaped

sections. Fig. 385 shows, diagrammatically, the method of drawing the section of the ordinary, or old egg-shaped type. The depth is one and a half times the greatest horizontal diameter. The top is a semicircle of radius R; the invert, or bottom, is a circular curve of $\frac{1}{2}R$ in radius, and the top and bottom are joined up by circular curves of radius $3R$. The sketch shows the centres from which the arcs are struck. Fig. 386 shows, in the same way, the method of drawing the new egg-shaped type, which is also known as the metropolitan. The bottom is more pointed, giving still better hydraulic mean depths for small flows. As in the last case, the depth is one and a half times the greatest horizontal diameter, but the radius of the invert is only half as great as in the previous case (i.e. $\frac{1}{4}R$). This necessitates, of course, a different radius for the connecting arcs; $2\frac{3}{4}R$ instead of $3R$.

Egg-shaped Sewers in Brickwork. Fig. 387 shows one method of constructing an egg-shaped sewer in brickwork. The invert is formed of terra-cotta blocks, which give a minimum of joints at this important point. They are moulded hollow, as shown, and are usually made with rebated joints at their ends, to secure perfect alignment; they may be filled with fine concrete before laying, to increase their strength. The inner ring of brickwork should be of blue Staffordshire bricks, which form a non-absorbent lining. The bricks should preferably be specially made and moulded to the proper radius, so as to permit of thin joints of uniform thickness, instead of wedge-shaped joints as they would otherwise be, though this involves considerable additional expense. Between the inner and outer rings of brickwork a thick line is shown. This represents a collar joint, consisting of a layer of cement mortar, about $\frac{1}{2}$ inch in thickness, the object being to give a second line of defence against leakage. Sometimes the sewer is only lined with Staffordshire bricks up to the commencement of the covering arch, A–B, the arch being of ordinary pressed, or engineering, bricks. The outer ring of brickwork should be of pressed bricks in all cases, and it is not important that the bricks should be moulded to the proper radius. Good cement joints are quite sufficient.

Invert Blocks for Brick Sewers. If the sewer is very large, the invert blocks may be built up of three pieces in the width.

The sketch (Fig. 387) shows the centres from which the arcs are struck, and from which the joints of the brickwork radiate. Concrete would, in any case, be put under the invert blocks, and up the sides of the sewer also, to form a support on which the brickwork can be laid.



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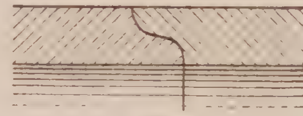

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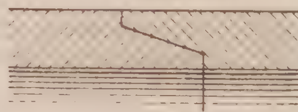
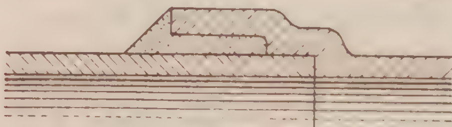


381

JOINTS FOR CONCRETE PIPES



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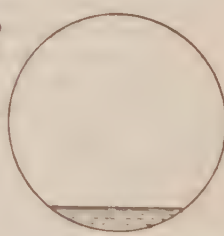
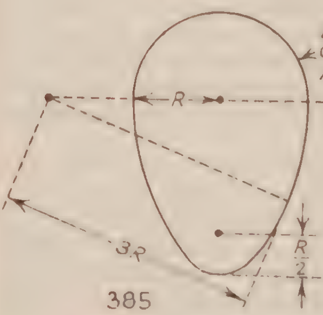
383

EGG-SHAPE AND CIRCULAR SEWERS COMPARED UNDER DRY WEATHER FLOW CONDITIONS



384

DIMENSIONS OF OLD EGG-SHAPE AND OF NEW



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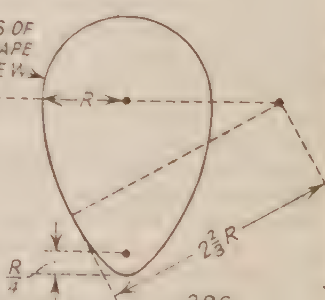


386

An alternative method of construction is shown in Fig. 388, in which the joints of the brickwork are not indicated. The sewer is partly in two rings of brickwork, and partly in one. Invert blocks are used, and the lowermost third of the height is lined with blue bricks, the remainder being of pressed bricks.

Dealing with Subsoil Water. Difficulty sometimes occurs by the rise of subsoil water as the work is being carried out.

Sometimes special invert blocks are used, having holes to admit the subsoil water to the spaces left in the hollow blocks, which form channels conducting the water to the lowermost end of the system. Another good method is that shown in Fig. 389. Below the concrete a small trench is cut to take a land drain of from 3 to 6 inches in diameter. The pipes are unglazed and are merely butt-jointed, without sockets. The trench is filled with broken stone. A third method, adopted where springs occur, is to place a pair of drain pipes on end, one on either side of the sewer, and fill them with gravel, leaving small openings in the sewer to allow the water to escape laterally to the top of the pipes and so down through them. The openings in the sewer are closed as the work proceeds.

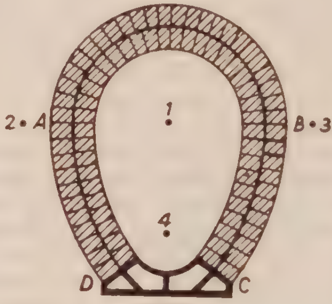
The methods of setting out the course, and gradients, of a sewer are similar to those adopted for a drain and described in the preceding chapter.

"Grips" for Pipe Sewers. In the case of pipe sewers, grips should be cut under the sockets to permit the joint to be properly made and to permit the pipe to be supported throughout its length.

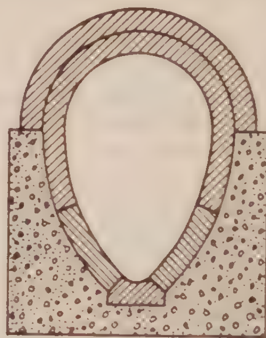
Timbering for Sewer Trenches. The timbering of the trenches also follows the same lines as given in Figs. 359 and 362, but for very bad ground the sizes of the timbers must be increased. Should the ground be very treacherous it may be necessary to leave in permanently the lowermost set of timbering, as otherwise the sides may fall in as the timber is removed, but it is seldom that this is necessary.

Sewers Laid in Running Sand. In the case of running sand, small sewers should be of iron pipes supported similarly to that shown in Fig. 365. So also should they be treated where they pass above ground, with additional strengthening given by a cross timber above the pipe, and longitudinal timbers connecting the heads of the piles.

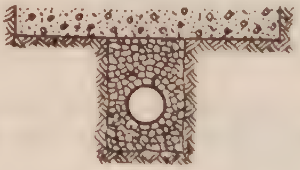
Open Cutting Versus Tunnelling for Sewers. Where the sewer is very deep below the surface, it is not economical to lay it by means of an open cutting. In such a case tunnelling should be resorted to. For a simple case, the tunnel might be formed by



387
TERRA-COTTA INVERT BLOCK USED IN BRICK EGG-SHAPE SEWER

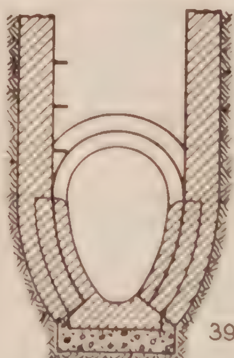


388
ALTERNATIVE EGG-SHAPE CONSTRUCTION

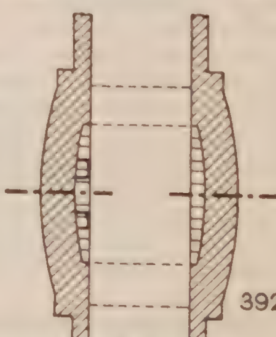


389
DRAINAGE FOR SUB-SOIL WATER UNDER BRICK SEWERS

390
TIMBERING FOR SEWER IN TUNNELLING



391
SECTION A-B



392
PLAN

BRICK MANHOLE FOR 30"x45" EGG-SHAPE SEWER

excavation, timbering the work on lines similar to those shown in Fig. 390. The timbers shown would be of about the following sizes: longitudinal members 9 × 3 inches or 9 × 4 inches, other members 9 × 9 inches, at horizontal intervals of about 5 feet. If the tunnel is large, it is often constructed by means of a compressed-air shield of the type used in the construction of tube railways, the tunnel being lined by cast-iron sections built up to form a circular lining, bolted together and well grouted, between and behind, with Portland cement grout. Such a tube could be completed to form the sewer by lining it with fine concrete washed with neat cement, or the sewer might be constructed inside it in the ordinary way.

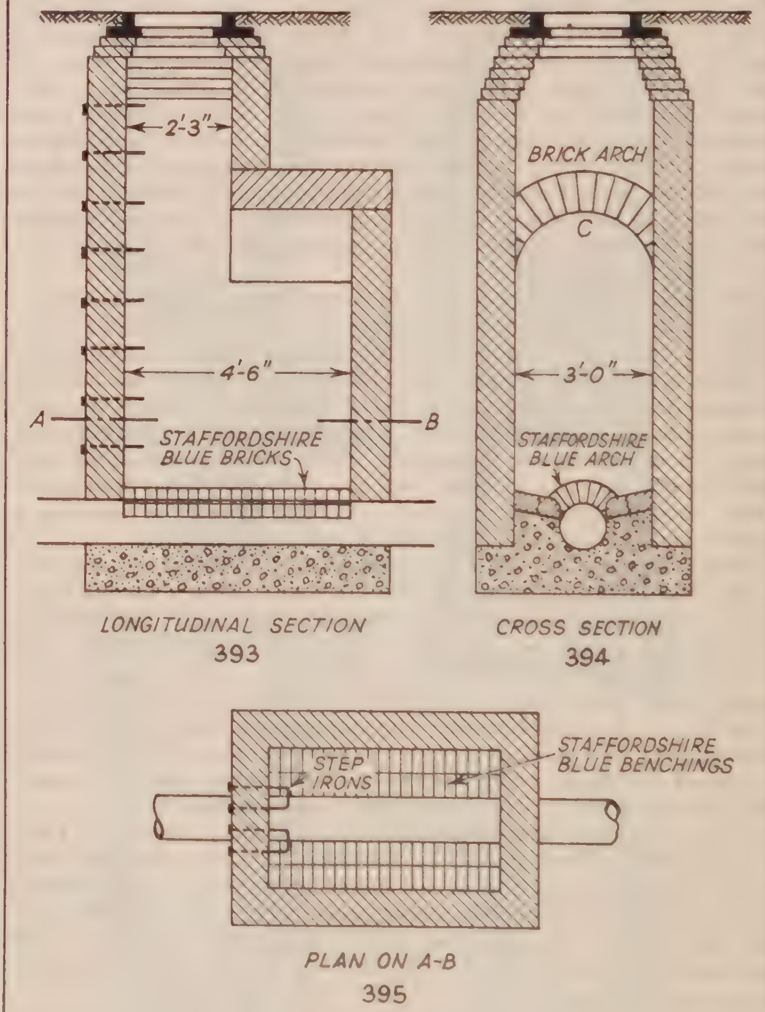
Sewer Manholes. Sewers should be laid in straight lines between points of inspection, manholes being placed at all changes of direction and gradient. Manholes should also be put at the junctions of main and branch sewers, and also at storm overflows, and, on straight lengths, at intervals of about 100 yards. Bends in small sewers should be formed entirely in manholes, but in sewers of large size, this is, of course, impossible. The forms of manhole vary with the size and type of sewer, and also with individual preference. Thus, with a small sewer, there is an opportunity of forming a reasonable benching at either side of the open channel.

Manholes may be built of brickwork or formed of concrete tubes, the latter being much the cheaper. Figs. 393-395 show details of a brick manhole on a 12-inch pipe sewer. The plan of the floor is shown in Fig. 395, while Figs. 393 and 394 show longitudinal and cross-sections respectively. An inspection of these details will show that the lower part of the manhole is 4 feet 6 inches by 3 feet internally, the upper part being reduced, by arching over, to a shaft of considerably smaller size. The benching is formed by means of Staffordshire blue bricks. Over the manhole shaft is a heavy iron frame with removable cover.

In all manholes step-irons must be built in as shown in Figs. 391 and 393. They should be protected against corrosion by a thick bituminous coating or by heavy galvanising. The benchings should be at, or slightly above, the level of the top of the pipes and should have enough crossfall for condensed water to run off them into the sewer, but not so much as to make it difficult for a man to stand on them.

The brick arch at C in Figs 393 and 394 may well be replaced with a reinforced concrete slab.

To prevent the weight of the walls cracking the pipes small arches are formed over the latter as shown in Fig. 394.



BRICK MANHOLE FOR 12 INCH CIRCULAR PIPE SEWER.

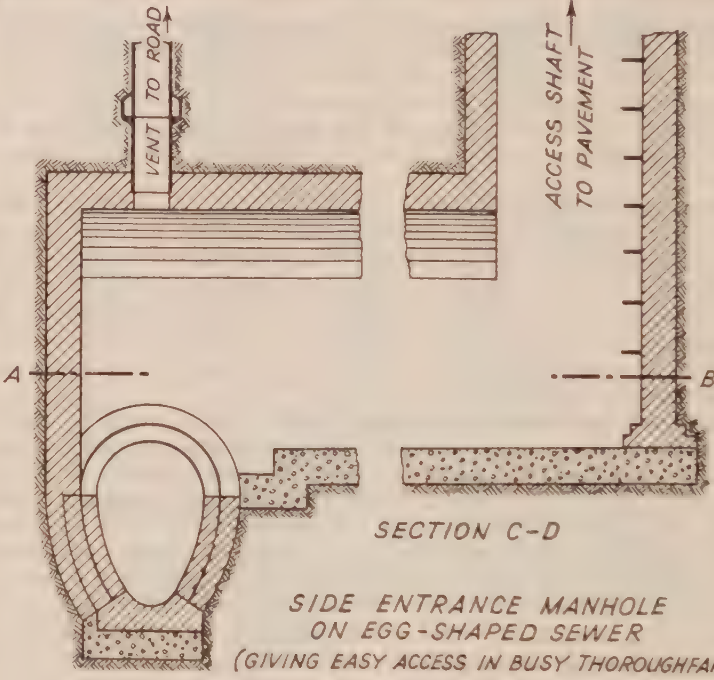
Manholes of Circular Plan. Some engineers prefer manholes of circular plan, on the ground that they are stronger, but they are rather more costly to construct, unless of precast concrete. If circular they should be made tapering upwards, so as to give adequate working room at the bottom and not too large a cover at the top. A disadvantage of this type of manhole is that it is difficult to get up and down the step-irons at the tapered part.

Manholes for Large Sewers. In the case of a larger sewer, the base of the manhole is of different construction. An example of this is shown in Figs. 391 and 392 The latter shows the plan, and the former a cross-section, of a manhole on an egg-shaped sewer. It will be seen that, without making the base of the manhole of exceptional size, there is no appreciable benching, but merely enough to give a foothold. The curved shape of the walls on plan is to give greater strength.

Manholes for Streets with Heavy Traffic. In a street in which the traffic is very heavy, manhole openings in the roadway are apt to cause considerable interference with the traffic; and it is then a common practice to provide manholes with side entrances, the latter being accessible from the pavement. Figs. 396 and 397 show details of such a manhole. An access shaft leads down from the pavement to a short tunnel leading to the side of the sewer. The tunnel is best formed by arching over, or using reinforced-concrete construction. The whole manhole can be formed of either brickwork or concrete, or partly the one and partly the other. A vent shaft is carried up to the roadway, in the form of a pipe, preferably to a ventilating column, but if it is not permissible to erect such a column, there will have to be a ventilating grating at street level. Ventilation in some way is very desirable in the case of a side entrance manhole, however much one may object to sewer openings at street level, as the large size of the manhole makes it a considerable receptacle for the accumulation of foul air.

Spacing of Manholes. Manholes should be from 75 to 120 yards apart; if for any reason two manholes must be placed at a rather greater distance apart than this, a lamphole should be provided between them.

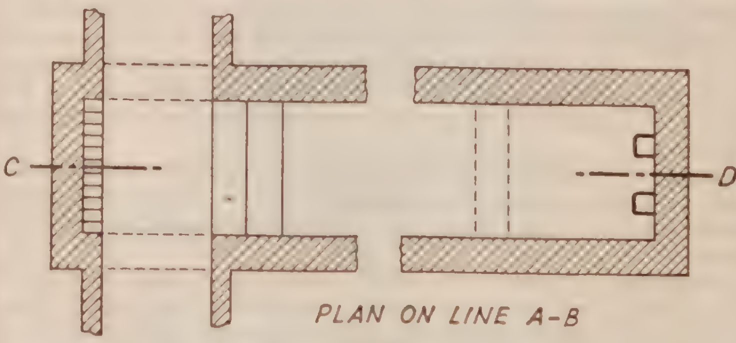
Lampholes. A lamphole can be formed of 12-inch or 15-inch pipes leading vertically down from the street to the crown of the sewer, cased round in concrete and surrounded with a block of the same material, or a stone slab at the top, on which is placed a removable cover. A lamp can be lowered down the shaft thus



SECTION C–D

SIDE ENTRANCE MANHOLE
ON EGG-SHAPED SEWER
(GIVING EASY ACCESS IN BUSY THOROUGHFARE)

396



PLAN ON LINE A–B

397

formed, and anyone in the next manhole on either side should be able to see the light and the condition of the inside of the sewer.

Sewer Gradients. While a sewer should, if possible, be laid with sufficient gradient to ensure the flow through it being a self-cleansing one, it should not be given an excessive fall; it is often said that excessive fall causes undue wear and tear on the pipes, but there does not seem to be any real evidence of this.

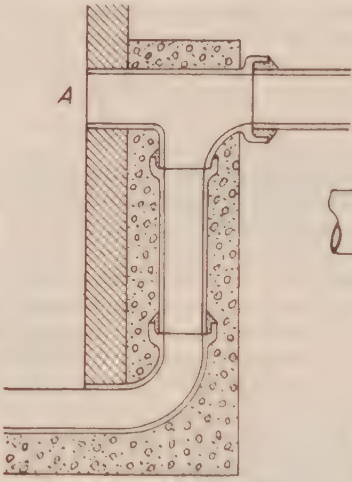
Ramps for Sewers. Where the fall is considered too great, the difficulty can be overcome by the use of a ramp similar to that shown in Fig. 398, but it is more usual, in the case of a sewer, to form it somewhat as in Fig. 419.

The incoming sewer, at the higher level, is fitted with a specially made vertical junction bend of easy radius, and is discharged into a vertical pipe, which should be of smaller diameter because the velocity in it will be so high. The energy of velocity is dissipated by eddying in its fall and its flow around the bend leading into the manhole. The junction bend at the top of the vertical pipe is also extended through the manhole wall at A; this is to give access and ventilation to the upper pipe. No stopper should be put at A, as this would impede ventilation. It will be noted that the vertical pipe is cased in concrete.

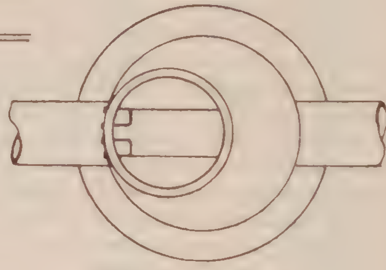
Disadvantages of Ramps unless Essential. Ramps should be avoided as far as possible, as they add considerably to the cost of the sewer; for the manholes must be deeper than if the sewer were laid at a uniform gradient; they also tend to churn up the sewage and liberate gas. They can in most cases be avoided by the judicious use of intercepting sewers.

Prefabricated Manholes in Concrete. Figs. 400 and 401 show sections of a concrete tube manhole, whilst Fig. 399 shows a sectional plan. It will be seen that whilst the shaft tapers, so as to secure good working room at the bottom with a cover of reasonable size at the top, yet the difficulty of access, which usually occurs with a tapered shaft, is avoided by making the upper and lower shafts tangential to one another on one vertical line; the step-irons are, of course, fixed on this straight side. The shafts are built up from precast rings, from 2 to 3 feet long, having "ogee" joints, as described for concrete tube sewers. The sewer inlet and outlet can be formed in one with the bottom ring, with either ogee or socketed joints, or, if preferred, the bottom ring will be supplied with stoneware pipes inset. The channel and benchings are formed in cement concrete and cement mortar after the bottom ring has been set in position.

Increased Gradients at Bends. Where a bend occurs in a sewer,

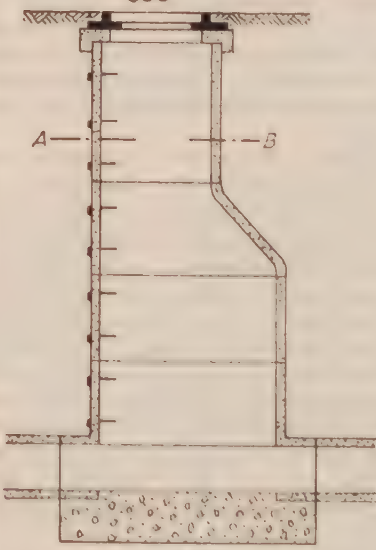


RAMP OR DROP MANHOLE
FOR STEEP GROUND
398



PLAN ON A-B
399

PLAN AND SECTIONS OF
PRE-FABRICATED CONCRETE
MANHOLE FOR 12" SEWER



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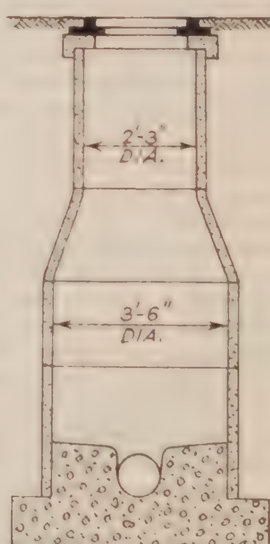


401

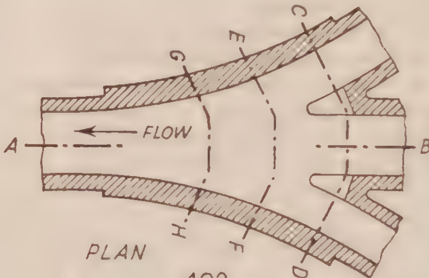
it should have a rather greater fall in its length than the uniform fall of the straight lengths it connects, to allow for increased friction. Where a small sewer discharges into a larger one, their inverts should not be at the same level, that of the smaller being above that of the larger, in order to prevent sewage standing in the smaller, and the consequent check on the velocity of its flow.

No Right-angled Junctions. There must be no right-angled junctions on a sewer, just as there should be none on a drain. All branch sewers should join the main with a bend pointing in the direction of flow. In the case of pipe sewers, this is easily effected inside the manhole by the use of proper stoneware channel junctions. In the case of an egg-shaped or other form of brick or concrete sewer, the junction is effected by the use of specially made stoneware junction blocks, built into the sewer at the required positions.

Bell-mouth Junctions. Where large main sewers join, a special form of construction becomes necessary, the form depending on the special condition to be met in each case. Figs. 402–406 give details of what is known as a bell-mouth junction between three egg-shaped sewers. The construction will be fairly evident from the illustrations. The walls of the sewer are thickened around the junction, as shown in Figs. 402 and 403. The former shows a plan and the latter a longitudinal section. The remaining illustrations show cross-sections of the junction at three different points. This example will give an idea of the method of construction in any somewhat similar case.

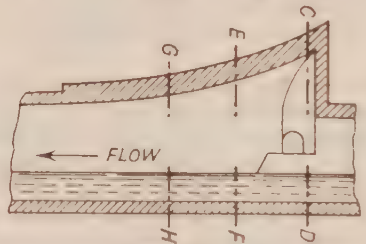
Road Gullies. Road gullies should be placed at intervals of from 40 to 75 yards, according to the longitudinal fall of the road. They can be of iron, stoneware, artificial stone, concrete or brickwork. They can also be either circular, square or rectangular on plan, but the general principles given for the design of any sanitary fitting will apply; that is to say, there should be a minimum of angles and corners. Fig. 407 shows a section through a well-known type of stoneware gully. The trap is formed in one piece with the main body of the gully, and an access stopper is provided to the drain leading to the sewer. In the example shown, the stopper is of iron, fitting into an iron frame with an airtight joint and secured by means of gunmetal thumb screws. The part below the trap is for the purpose of intercepting the mud, which is removed at more or less frequent intervals.

One of entirely different construction is shown in Figs. 408 and 409. It is built of brickwork, lined inside with cement mortar, covered by a stone slab, and surmounted by the usual heavy iron

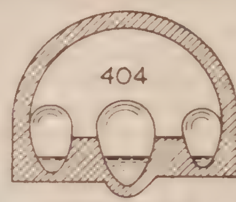


PLAN

402



SECTION A-B

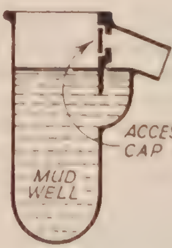


SECTION C-D

SECTION E-F

SECTION G-H

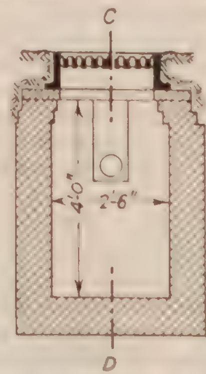
403. BELLMOUTH JUNCTION SHOWING TWO 18" SEWERS CONVERGING TO JOIN A 27" MAIN SEWER



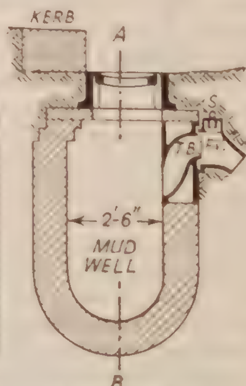
407

STONEWARE ROAD GULLEY

NEEDS SETTING ON CONCRETE AND SURROUND OF SAME TO TAKE HEAVY IRON GRATING AT GUTTER



SECTION A-B



SECTION C-D

408 & 409. BRICK ROAD GULLEY WITH STONEWARE TRAPPING BLOCK

grating. Fig. 408 shows a longitudinal section and Fig. 409 a section at right angles to the kerb. The trap is formed by means of a stoneware trapping block, T.B., in two pieces, a light flap valve being added at F.V. if desired. There is no direct access to the drain from the gully, but an access stopper exists just under the roadway surface as shown.

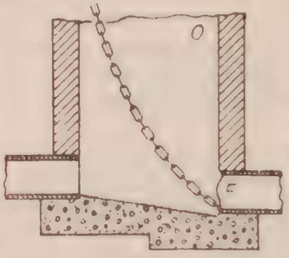
Flushing Sewers. Flushing is often necessary for sewers. For example, if a sewer is designed for prospective requirements and will, for some time, receive much less than its ultimate quantity, it should be provided with means of flushing. So also, if it is of a very flat gradient, insufficient to cause it to be self-cleansing.

There are many means of flushing. Automatic flushing tanks have been dealt with under the heading of drainage, and large tanks of that kind, built of brickwork and of course placed underground, are often used. Such a tank should always be provided at the upper or dead end of each section of any sewers that need flushing.

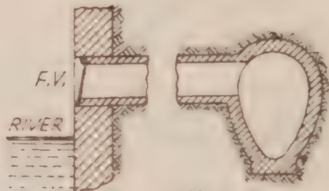
Any flushing arrangements should have for their object the maintenance of an effective velocity through the sewers, for a sufficient time to remove any deposits and cleanse the sewer.

One of the simplest ways of flushing is by damming back the sewage and then liberating it when it has attained a sufficient head, or depth, in the manhole. Special flushing gates, sluices, etc., are fixed in manholes for the purpose. An old-fashioned method was to use a board across the outlet of the manhole, fitting into grooves at its ends and lower edge, but a few inches away from the mouth of the outlet. The sewage accumulated behind the board, which was then pulled up by means of chains in order to liberate it. This had the advantage that if the sewage was allowed to rise above the top edge of the flushing board, it simply flowed over and through the sewer. If a sluice or gate is used, a sort of inverted ramp should be provided as an overflow in case of neglect to open the sluice, the manhole end of the ramp being always open.

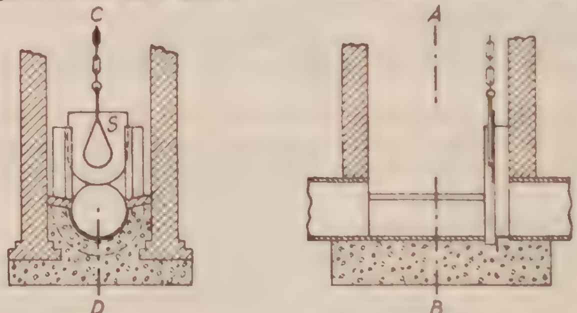
Flap Valves for Flushing. The arrangement of the base of the manhole when a flap valve, F, is used is shown in Fig. 410. The floor is slightly sunk in front of the outlet, to permit of the flap readily opening. A strong chain is attached to the flap and fastened loosely near the top of the manhole. The chain shown in the sketch is unnecessarily heavy, but a strong one is essential. The overflow is omitted, but the mouth of it would be about at O, and the pipe would pass down to join the outlet sewer a few feet from the manhole. Flap valves sometimes have floats attached



410
FLAP VALVE TO AID FLUSHING
12" SEWER IN FLAT AREA



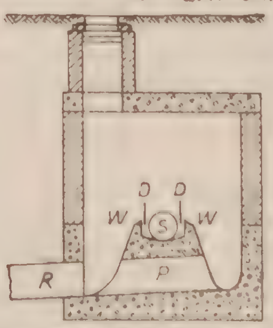
411
STORM WATER OVERFLOW
TO RIVER – FLAP VALVE TO
PREVENT BACK FLOODING AT
HIGH TIDE IF RIVER IS TIDAL



SECTION A-B

SECTION C-D

412 & 413. PENSTOCK ON 18" SEWER TO AID FLUSHING
IN FLAT GRADIENTS



414 OVERFLOW CHAMBER WITH
DOUBLE SPILLWAYS OR WEIRS
FOR STORM WATER

415. SIPHON SPILLWAY TO
REMOVE SURPLUS STORM
WATER BUT RETAIN
SOLIDS AND FLOATING
DEBRIS

to them, which are intended to lift them automatically when the sewage reaches a certain height, but the plan is not very reliable.

Tipping Tanks. Tipping tanks are also used for flushing sewers, but they are only suitable for small volumes of flow.

Penstocks for Flushing. Another method is shown in Figs. 412 and 413, which show a longitudinal and cross-section respectively of the base of a manhole fitted with a penstock or sluice, S. The latter is merely an iron plate or door, fitting into a grooved frame of iron and capable of being rapidly opened by the pull of a chain from above. The frame in the example shown is fixed a little away from the outlet so as to allow the sluice to form an overflow. The sections show the sluice open.

For properly cleansing the sewers it is necessary to introduce plentiful supplies of water, and to do it systematically. In dry weather, more frequent flushings are, of course, necessary, and in times of epidemics disinfecting liquids may be added to the water.

Other Flushing Methods. Where a river is near, it is generally possible to obtain an ample supply for flushing, and on the sea-coast many towns use sea-water with more or less beneficial results. Water may be taken from the street hydrants and admitted to the sewers through manholes or lampholes. Storm water may be collected and used with advantage. Before the use of automatic flushing tanks became general, an ordinary tank was often used. It was constructed of brickwork or concrete, with cement lining, with a capacity of from about 1500 to 1800 gallons. It could be filled from hydrants in about twenty minutes and its contents were then allowed to pass out through a 9-inch pipe, this taking only about three minutes, and producing a powerful scouring effect. Automatic arrangements for flushing are, however, much more satisfactory than those requiring manual attention.

Storm Water Overflows. When the combined system of sewerage is in use, it would be very costly to construct long lengths of main sewer large enough to carry away all the rainfall which finds its way into the sewers during a heavy storm, while it would also be a severe tax on the sewage disposal plant to deal with such large volumes. It is usual, therefore, at selected points not far removed from streams or other watercourses, to put in storm overflows, by means of which excess of rainfall is discharged into relief sewers leading directly to watercourses.

Provided that each overflow is at a suitable level, the watercourse will not be unduly polluted thereby; for during the early part of the storm, when the street washings and other objectionable matter will be carried into a sewer, the water will be rising toward

the overflow level. When that level is reached the storm-water should be running clear and the sewage will be so diluted by it that it is not likely to cause a nuisance in a stream to which it is discharged, especially if care is taken to avoid taking light floating debris and heavy solid matter over the storm-water overflow.

The Ministry require that the overflow level shall be at such a height that it will not function unless the discharge of the sewer is more than six times the mean dry weather flow.

One simple method of doing this is illustrated in Fig. 411, a relief sewer being built from the main sewer to a river. A flap valve is shown at its outlet, to prevent back flow when the level of the river is unusually high. The level of the invert of the relief sewer at its upper end is such that when water is at this height the main sewer is carrying six times the dry weather flow. This arrangement, however, will seldom be satisfactory, because it is unlikely that sufficient water could get into the relief sewer, in a heavy storm, to prevent the main sewer getting completely full and surcharged; in that case, although the relief sewer would be running full bore, much more than six times the dry weather flow would still be left passing on to the outfall, or to the next overflow.

It is therefore usual to install a long overflow weir, or two such weirs, in a special manhole called an overflow chamber, as shown in Fig. 414. The object of having two such side weirs is, of course, to reduce the size and cost of the chamber. In the illustration S is the main sewer leading out of the chamber; this can be of less diameter than the sewer flowing in, because of the help given to it by the relief sewer. Inside the chamber the water flows in a nearly flat channel, at each side of which is a weir W. The sewage which falls over the left overflow passes directly to the relief sewer R, whilst that which falls to the right does so after flowing through the passage P. It is often, but not always, the practice to provide "dip plates", D, to prevent floating solids from being carried over the weirs to the relief sewer. If desired, the tops of the weirs may be adjustable iron plates.

Whilst the provision of a storm water overflow of this type can be made, by placing it at the correct height, to function only when the inflow in the main sewer exceeds six times the dry weather flow, it would be wrong to suppose that all that excess will pass over the weirs. As the water level rises higher above the sill of the weir the discharge of the overflow will increase, but so will the discharge of the outgoing main sewer.

Siphon Spillways. To overcome this objection, in some recent schemes siphon spillways, such as that shown in Fig. 415, have

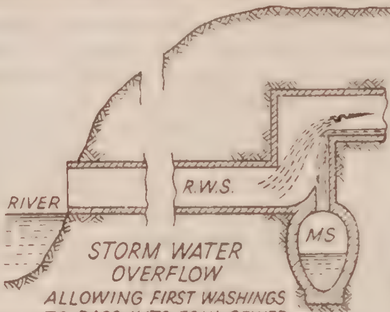
been introduced. When the main sewer, S, is carrying six times the dry weather flow the water level in it is at A and any small rise in that level will cause water to flow over the throat of the spillway; under this condition there is no siphonic action, because the throat is kept at atmospheric pressure by the air pipe P. If, however, the water level rises to B, the mouth of the air pipe will become sealed, with the result that air will be carried away from the throat by the flow of water and siphonic action will begin. The siphon will then discharge full bore, the head on the siphon being the difference between the water level in the main sewer and that in the relief sewer, R. Because the siphon inlet is well submerged, except at the tail end of the discharge of storm water, very little of the light floating matter will enter, whilst, because it is so high above the invert of the main sewer, none of the heavy solids will do so.

Use of Leap Weirs. One defect in the separate system of sewerage is that the first washings of streets, roofs and yards in a storm, especially after a drought, are apt to be very foul and therefore unfit for discharge into a river without treatment. To provide against this the leap weir, illustrated diagrammatically in Fig. 416, may be useful, though it is in fact seldom installed. When only a small quantity is flowing in the rainwater sewer, the velocity will be low and the water will fall almost vertically into the main sewer, marked M.S., of the foul sewage system. If the rainwater sewer is fairly fully charged the velocity will be much higher and the water will leap across the gap to the lower rainwater sewer, R.W.S. It is obvious that the success of this method depends on the proper proportioning of the width of the gap and the amount of fall to the lip of the weir.

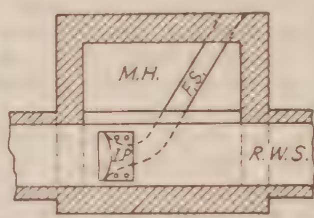
The leap weir is not suitable for use as a means of getting rid of excess of flow in a combined sewer, because when the velocity of the stream is high all the flow would be carried to the river, whereas the Ministry of Health require that six times the dry weather flow shall remain in the sewer.

A modified form of leap weir is shown in Fig. 417. An adjustable iron plate, I.P., is fixed on the invert of the rainwater sewer, over the mouth of an opening, leading to a foul sewer, F.S. When only a small quantity of water is passing along the rainwater sewer, it will all go through the opening to the foul sewer, but when there is considerable velocity very little will be intercepted in this way.

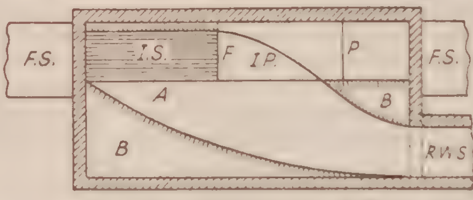
Surface Water Separator. Fig. 418 shows an appliance introduced at Birmingham many years ago which attempts to divert the excess over six times the dry weather flow in a manner different



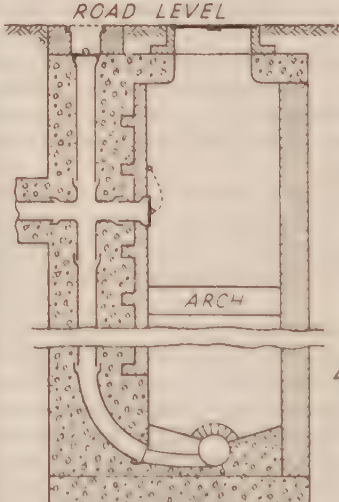
STORM WATER OVERFLOW
ALLOWING FIRST WASHINGS TO PASS INTO FOUL SEWER
416



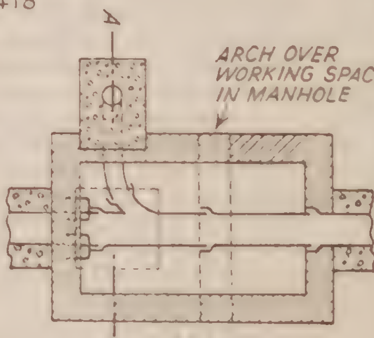
ADJUSTABLE KNIFE EDGE PLATE FORM OF STORM WATER SEPARATOR
417



STORM WATER SEPARATOR
SIMILAR TO FIG. 417 WITH INCLINED GATE SCREEN TO DEFLECT FLOATING DEBRIS DOWNWARDS INTO FOUL SEWER
418



SECTION A-A



PLAN

419. PLAN AND SECTION OF DROP MANHOLE (OR RAMP)
SHOWING 6" SEWER AT HIGHER LEVEL JOINING 9" SEWER AT LOWER LEVEL (AS RECOMMENDED IN BRITISH CODE OF PRACTICE (C.P. 301)) WITH ACCESS CAPS TO HORIZONTAL AND DROP SECTIONS.

from any of the foregoing. A horizontal flat plate, F.P., is fixed across the foul sewer. F.S., at the required height to cut the flow into two parts; one that below six times the dry weather flow, and the other, that above it. On the flat plate is fixed a vertical curved plate of iron, I.P., which diverts the upper flow into the rainwater sewer, R.W.S. At the entrance to the manhole is an inclined wire screen, I.S., with an upright triangular side at A. This screen forms a sort of basket, which prevents rags, paper, and other rubbish collecting at the edge of the flat plate, or passing into the rainwater sewer.

Inverted "Siphons" at Stream Crossings. Where a sewer has to cross a stream, railway cutting or other similar feature, an inverted siphon has often to be used. They are objectionable features and should be avoided wherever possible. They usually consist of two sloping lengths meeting a flat length between them. They should be formed of cast-iron or steel pipes, treated with the Angus Smith or other process, and should be laid in duplicate. There should be a good manhole at each end, and if the length is very great it is wise to carry up a vent shaft at the middle to prevent the siphon becoming air-locked. There is always a tendency to blockage in the flat length, and it is usual to adopt some device to check this, such as putting a permanent large chain through from end to end, so that it can be pulled backwards and forwards to stir up the silt. The object of laying them in duplicate is that, in case of trouble, the sewage can readily be diverted from one to the other.

Bridge Crossings. Where sewers cross bridges, they should be of iron or steel pipes, owing to the vibration. Sometimes they are accommodated between the girders of the bridge or, if this is impossible, they are fixed to brackets at the side.

Sewer Ventilation. We come next to the question of the ventilation of sewers, a question which has given rise to much controversy in the past.

On the one hand, if the sewage is of normal domestic character and the sewers are well constructed and have good gradients, foul air should not be generated in any very appreciable quantity and it should not be dangerous to the health of those who happen to inhale it. In such cases all that seems necessary is sufficient means of ventilation to allow air to escape from the sewer, when the water level rises through heavy rainfall, and to allow air to enter the sewer when the water level subsides.

On the other hand, if the sewers are so flat in gradient that the discharge is much delayed and solid matters settle and decompose,

gases will be given off which are highly offensive, and even dangerous to the health of some persons, for some are much more adversely affected by bad smells than others. Much, too, depends on the character of the sewage; decomposing sewage will always give off carbon dioxide, marsh gas and ammonia, which should be classed as asphyxiating, rather than poisonous, gases, but some sewage also gives off sulphuretted hydrogen, which is definitely poisonous. Trade effluents often contain chemicals which, on mixing with one another, may react chemically and form gases of a poisonous character. The possibilities of coal gas, leaking from gas mains, and of petrol from garages, with consequent formation of explosive mixtures with air, must also be considered. In all such cases adequate ventilation is essential for the general health of the community, for the safety of men who occasionally have to enter the sewers, and for the prevention of damage to the sewers by explosion.

That the danger resulting from inadequate ventilation is in some cases a very real one is illustrated by the report of a Committee, appointed by the Home Office and the Ministry of Health in 1933, to enquire into the precautions that should be taken for the safety of persons entering sewers. They recommended that, before a man enters a sewer by way of a manhole, the cover thereof and those of the manholes on either side shall be removed for at least half-an-hour, at the end of which time tests shall be made for sulphuretted hydrogen, for asphyxiating conditions, and for inflammable gases; unless these tests prove satisfactory no one should enter the sewer without a special respirator.

Sufficient has probably been said to show that a certain amount of ventilation is essential and that in some cases a thoroughly efficient system is highly desirable. It is, however, often difficult to secure this result without causing a public nuisance.

Combined Sewer and Drain Ventilation. For many years, a section of municipal engineers have agitated for the prohibition of the intercepting trap between house-drains and the public sewer until, to-day, many local authorities, encouraged by the Model Code, have altered their local by-laws so as to make the use of the intercepting trap optional to the householder or (more frequently) forbidding its use and that of the mica flap air inlet altogether.

When the sewers are modern and are provided with a reasonable fall, the sewer air is very little worse than that in a well-constructed house drain, and there seems little reason to object to the sewers and the drains to be ventilated as a single unit. When this is

done, the local authority provides large fresh-air inlets at intervals in quiet spots and the air flows along the sewer, entering the many house drains along the route, to discharge well above eaves level, through the many soil-pipe vents of the houses served. When conditions are good, the benefit to the sewer ventilation is inestimable and that of the many private drains is satisfactory. The disadvantage, in the view of many surveyors and architects in private practice, is in the loss of individual control of the separate house drain units. Their view is that where the local authority's air inlets are widely spaced, nearby house drains get a plentiful supply of air and drain ventilation is good, but house drains farthest from the air inlets have the air flow reduced almost to vanishing point. It is a problem, however, for the local authority's surveyor or engineer, not for the individual householder, and if the local authority sees that air inlets are placed at sufficiently close intervals along the sewer, the combined sewer and drains ventilation scheme appears to be satisfactory.

Sewer Ventilation through Open Gratings at Street Level. The use of open gratings at manholes is the easiest method and has been greatly used in the past. The use of open gratings dates from about 1834. The system is open to considerable objection owing to the more or less frequent offensive emanations from the gratings. Complaints on this ground led to gratings being closed one by one, and the substitution of vertical shafts, it being thought that the high shafts would act as outlets and the remaining gratings as inlets.

Investigations by Mawbey and De Courcy Meade. Some valuable investigations were, however, carried out by E. G. Mawbey, formerly Borough Engineer of Leicester, and by T. De Courcy Meade, formerly City Engineer of Manchester.

Mawbey carried out thousands of tests, at all times of the year, in Leicester, and came to the conclusion that surface gratings are unnecessary, vertical shafts alone being sufficient. He found that the shafts gave both inward and outward air currents, but usually the latter, which were in all cases the more vigorous. In a thousand tests, he found the average upward current to be 162 feet per minute, and the average downward current to be 34·6 feet per minute.

De Courcy Meade's experiments corroborate the results obtained by Mawbey, Meade pointing out that the shafts act indifferently as both inlets and outlets, the air currents being governed by the difference in temperature between the internal and external air, the rise and fall of the sewage, the construction and character of

the sewer, etc. All the conditions are liable to be neutralised and reversed by the direction and force of the wind, while the heat of the sun, of course, affects the draught through any particular shaft.

In the face of these results there has been a growing tendency, in recent years, towards the use of vertical shafts alone. These may be erected against the sides of buildings, but local authorities find a difficulty in obtaining the necessary permissions. An owner runs a serious risk in granting such a permit, since, if the shaft is not thoroughly well constructed and maintained, there is the possibility of nuisance by reason of defective joints. Further, the settlement of the building, and consequent settlement of the shaft, may lead to a fractured pipe or broken joint at the foot of the shaft, allowing the soil around to become impregnated with sewer air. In some few instances shafts have consequently been erected against buildings, but not attached to them. All iron vent shafts should have rust pockets at their feet.

Sewer vent shafts should preferably be carried up independently of buildings, either beside the kerb or in the centre of the roadway, to a height at least equal to that of the ridges of the roofs of the abutting houses. High lamp standards have been used as vent shafts in some places, notably at Southport. In some cases the shafts have been carried up beside, and attached to, telegraph poles, but there is a risk of damage to the joint at the foot by reason of the motion of the pole in a high wind.

The sizes of the shafts depend on the size of the sewer, but they vary from 6 to 9 inches in diameter, as a rule, and are put at about 200 yards apart. The system of ventilating by detached shafts is simple, sound, calls for a minimum of attention, and, compared with more elaborate systems, inexpensive.

Deodorising Systems. Systems of deodorisation are of many forms, the two best known being the "Reeves" and the "Caink" systems. In the former, recesses are formed in the manhole of the sewer, containing two vessels, charged with chemicals which mix continuously, forming gases which purify the sewer air. In the Caink system an apparatus is used in the form of an air filter and deodorant. These systems have never been very popular among local authorities and are now but little used.

Use of Mill Chimneys. In some few towns the connection of the sewer to mill chimneys has been adopted, but with little success. The draught is so great near the chimney that it tends to unseal the neighbouring traps, while 200 yards away it has hardly any effect. The system is obviously limited—even in industrial towns—

by the inadequate supply of mill or factory chimneys suitably placed. It is interesting to note that the first attempt in this direction was made on the main sewers of London by Sir Joseph Bazalgette, who used a furnace in the tower of the Houses of Parliament with but poor results.

The Shone and Ault System. An interesting experiment in ventilating sewers and house drains as a single unit was the Shone and Ault System. In this system (invented when intercepting traps were compulsory in all districts) powerful suction fans at selected points on the sewerage system drew out the air from sewers and house drains alike as a single unit and discharged it, after filtering and deodorising in quiet spots where no nuisance could be caused, even if the deodorisation was not complete. The air inlets were the scores or hundreds of house soil and "vent" pipes, while the intercepting traps were by-passed by special adjustable valves on the cleaning arms of the interceptors. There was thus no risk of so great a suction or vacuum building up as would endanger the safety of the trap seals. The system was expensive to install and needed constant supervision to keep the by-pass valves in adjustment and perhaps for that reason never became popular.

Volume of Sewage to be Carried. Next consider the calculation of the volume of sewage to be carried by the sewers, and the determination of their size.

Dry Weather Flow. The volume of dry-weather flow in any sewer, if only sewage be admitted, may be assumed to be equal to the amount of the water supply, say 25 to 30 gallons per head per day. The volume carried is not, however, uniform throughout the day, owing to the varying quantities of water used in houses at different times of the day. In making provision for the maximum dry-weather flow of sewage, it is usual to assume that one-half the daily quantity is discharged in from six to eight hours. If, therefore, we take the daily quantity at 25 gallons per head, the maximum flow will be at the rate of 12½ gallons per head in, say, six hours, or about 2 gallons per head per hour.

Surface Water or Rainfall. The amount of rainfall which it is necessary to provide for in the sewers is a difficult matter to determine and is often underestimated. The amount the sewer should receive below storm overflows is usually fixed by the Ministry of Health at six times the dry-weather flow, but the amount to be received above such overflows must be estimated. As excessive rainfalls occur but seldom, it is unusual to go to the expense of providing against possible damage from the sewers overflowing

at very rare intervals, though where such damage might be great the expense would be justified.

Storm Water. For the purpose of designing the main sewerage system of a town, a method first proposed by Mr. Lloyd Davies is usually adopted for estimating the amount of rainfall to be provided for. The argument underlying this method is as follows:

Rain storms of abnormally high intensity do not last for a long period and therefore will not be such a heavy burden on the sewers as storms of rather less intensity lasting for a long period; a large part of the rain will be used in filling up the sewers to their greatest capacity. On the other hand, very prolonged rainfall will not be of great intensity and the sewers will be able to carry away the water, as it falls, without great difficulty. In between these extremes there is a type of storm which will prove the greatest burden upon the sewer which we have under consideration.

This storm is one which lasts just so long that the first drops of rain, falling on the uppermost part of the drainage area, reach this sewer at the same moment as the last drops are falling in its immediate vicinity. This period of time is known as the "time of concentration". It is calculated by dividing the distance between the uppermost part of the drainage area and the sewer, by the probable velocity of the water in the sewers from the one point to the other, and adding thereto an allowance of about five minutes for the time which is required for the water to get into the sewers by way of rainwater gutters, downpipes, gullies, etc.

The next question to be considered is the greatest intensity of the storm which will last for a period equal to the time of concentration. Careful observation of storms, over a period of years in many localities, show that this can be determined with reasonable accuracy by one of the following formulae:

If the time of concentration is not more than twenty minutes,

$$R = \frac{30}{T + 10}.$$

If the time of concentration is not less than twenty minutes,

$$R = \frac{40}{T + 20}.$$

In the above formulae R is the rainfall in inches per hour, and T is the time of concentration in minutes.

Impermeable Surfaces. The amount of impermeable surface in the drainage area above the point in question is next ascertained.

The volume of storm water to be provided for is then calculated by the following formula:

$$Q = A \times R,$$

where Q = volume in cubic feet per second,
A = impermeable area in acres,
R = rainfall in inches per hour.

Example Working for a "Combined" Sewer. Find the diameter to be given to a circular sewer, to be laid at a gradient of 1 in 500, at the lower end of a drainage area of 400 acres, which will eventually house a population of 20,000 persons, drainage being on the combined system. The general gradient of the drainage area is such that the sewers above have a velocity of about 4 feet per second when discharging at maximum rate.

First determine the volumes to be carried.

Dry Weather Flow. Assume that the sewage proper is 25 gallons, i.e. 4 cubic feet per head per day.

Mean discharge $= 20{,}000 \times 4 = 80{,}000$ cu. ft. per day.

About one-half of this must be estimated to pass through the sewer in six hours; this means that the maximum dry-weather flow is twice the mean rate.

$$\text{Max. D.W.F.} = 2 \times 80{,}000 = 160{,}000 \text{ cu. ft. per day.}$$

$$= \frac{160{,}000}{24 \times 60 \times 60} \text{ cu. ft. per sec.}$$

$$= 1{\cdot}85 \text{ cu. ft. per sec., or say } 2 \text{ cu. ft. per sec.}$$

Storm Water. It will be assumed that a study of the map of the drainage area shows that some parts of the area are 6000 feet from the sewer which we are considering.

This length is divided by the velocity of 4 feet per second (= 240 feet per minute) and five minutes is added for time of entry.

$$\text{Time of concentration} = \frac{6000}{240} + 5 \text{ minutes.}$$

$$= 25 + 5 = 30 \text{ minutes.}$$

$$\text{Rainfall} = \frac{40}{T + 20} \text{ in. per hour.}$$

$$= \frac{40}{30 + 20} = \frac{4}{5} \text{ in. per hour.}$$

In order to estimate the probable area of impermeable surface,

when the land is fully developed, it may be necessary to examine estate plans, provisions of a town planning scheme, etc. Comparison of the figures of the population and the area, given in the question, suggest however that the whole of the land will be developed for building at about ten or twelve houses per gross acre, under which conditions the area of roads will amount to about 15 per cent. of the whole land, and the area of roofs and paved yards to about the same percentage. Thus

$$\begin{aligned}
\text{Impermeable area} &= 30 \text{ per cent. of } 400 \text{ acres} \\
&= 120 \text{ acres.} \\
\text{Storm water} &= A \times R \\
&= 120 \times \frac{4}{5} = 96 \text{ cu. ft. per sec.}
\end{aligned}$$

Adding to this the maximum D.W.F. we find we have to provide for a total discharge of 98 cubic feet per second. This should be carried by the sewer when flowing not more than two-thirds full, under which condition the cross-sectional area of the water is $0{\cdot}556d^2$ and the hydraulic mean depth is $0{\cdot}29d$, where d is the diameter in feet.

Using the formulae, already given for drainage, $Q = AV$ and $V = C\sqrt{RS}$, and combining these into the formula $Q = AC\sqrt{RS}$,

$$\begin{aligned}
96 &= 0{\cdot}556d^2 \times 100\sqrt{0{\cdot}29d \times \frac{1}{500}} \\
&= 55{\cdot}6d^2 \times \sqrt{0{\cdot}00058d} \\
&= 55{\cdot}6d^2 \times 0{\cdot}024\sqrt{d} \\
&= 1{\cdot}33d^2 \times \sqrt{d}, \\
\therefore d^2\sqrt{d} &= \frac{96}{1{\cdot}33} = 72.
\end{aligned}$$

A few trials of likely values of d show that

$$\text{If } d = 5 \text{ ft., } d^2\sqrt{d} = 25\sqrt{5} = 56.$$
$$\text{If } d = 6 \text{ ft., } d^2\sqrt{d} = 36\sqrt{6} = 88.$$

The correct value of d seems therefore to lie about midway between 5 and 6 ft. Try $d = 5\frac{1}{2}$ ft.

$$\begin{aligned}
\text{Then} \qquad d^2\sqrt{d} &= (5{\cdot}5)^2 \times \sqrt{5{\cdot}5} \\
&= 30{\cdot}3 \times 2{\cdot}34 = 71.
\end{aligned}$$

The diameter should therefore be 5 feet 6 inches.

For small drainage areas, such as a building estate, the method of calculating the storm water, described above, will result in a

sewer of extravagant size, in view of the fact that a slight surcharge of sewers will not usually be dangerous, and a slight and very occasional flooding of roadways and other paved surfaces will not be more than a temporary inconvenience; whilst if, on the other hand, a large sewer is constructed to avoid such inconvenience, the depth of sewage in it will in dry weather be so small, that solid matters will not float and will therefore be left deposited in the sewers until the next storm comes, or until the sewers are flushed by the local authority. It is therefore more usual in such cases to provide for a much smaller intensity of rainfall when dealing with quite small areas, such as $\frac{1}{4}$ inch per hour on impermeable surfaces.

Hydraulic and Rainfall Tables. Various sets of tables are obtainable, giving the velocity and discharge of sewers of various sizes, according to their inclination, and these, of course, furnish the most ready method of arriving at the size necessary for any particular case. If tables are, for any reason, not available, the size must be determined by the principle illustrated in the foregoing example.

Gradients for Sewers. The gradient to be given to sewers is usually fixed within certain limits by the physical features of the district and the level of the point of outfall; but every effort should be made to secure that gradients shall be such that the sewer is self-cleansing, not only when carrying its maximum quantity of sewage, but also in dry weather. If the flatness of the district makes this impossible, the inclination should at least be sufficient to give a self-cleansing velocity when the sewers are being flushed, and automatic flushing tanks should be provided.

Self-cleansing Velocities for Sewers. A small sewer, say 12 inches and less in diameter, should have a velocity of flow of not less than 3 feet per second to keep it free from deposit; a sewer from 12 to 24 inches in diameter $2\frac{1}{2}$ feet per second, and large sewers 2 feet per second.

The smallest-sized sewer should not be less than 6 inches in diameter, and then only where there is no chance of its being extended higher up.

There is sometimes a difficulty in sewering a district, owing to the levels being such that a gravitation system is out of the question. Pumping stations can in such case be provided, or the case may be met by the provision of a series of Shone ejectors, or sewage lifts, both of which have been described in Chapter X. The sewage lift, however, is seldom economical for use on a large scale, owing to the large volume of water required to operate it.

CHAPTER XII

Sewage Disposal

A most interesting branch of the subject of drainage and sanitation is that of sewage disposal or purification. The problem is by no means a simple one, and the effectual purification can only be accomplished by the earnest collaboration of the engineer, the chemist and the bacteriologist. Very few, if any, men can be regarded as combining a thorough knowledge of these three professions, and it has been truly said that the engineer who poses as a chemist, or the chemist who poses as an engineer, usually makes a conspicuous fool of himself.

Pollution of Rivers in Last Century. Many years ago the condition of our streams and rivers was exceedingly bad, owing to the discharge of crude or only partially purified sewage, and it became necessary to pass the Rivers Pollution Prevention Act of 1876, Section 3 of which provides that local authorities and other parties shall use the best practicable and available means to render harmless the sewage discharged into streams and rivers, while the Rivers (Prevention of Pollution) Act, 1951, gives River Boards the right to control the discharge of trade effluents into streams, and insists on a minimum standard of purity before the effluent of sewage purification plant and apparatus or plant for dealing with liquid trade waste can be discharged into streams and rivers.

Need for Purification. It is necessary, therefore, to see that the sewage, before being discharged into streams, is purified and not clarified only; that is to say, not only shall the matters in suspension be removed, but the organic impurities also, so that secondary decomposition shall not set up after the effluent water has commingled with the water in the stream.

Sewage is a very complex substance, its composition varying tremendously. It is obviously the fact that there must be a great difference, for example, in the composition of the sewage from a purely residential district and that from a large manufacturing town, owing to the sewers receiving the waste liquids from the trades and manufactures, which in themselves, again, differ in nature in one town from those in another.

Composition of Sewage. It is difficult, therefore, to give anything very definite as to the chemical composition of sewage

The Rivers Pollution Commissioners, in 1876, published a table of compositions of sewage for both water-closet towns and privy midden towns, but the latter are so rapidly becoming obsolete that they hardly call for notice now. An abstract of the table referred to is given below as regards water-closet towns, i.e. towns discharging principally ordinary domestic sewage into the sewers:

Average Composition of Sewage

Total Solid Matters in Solution	Organic Carbon	Organic Nitrogen	Ammonia	Total Combined Nitrogen	Chlorine	Suspended Matters		
						Mineral	Organic	Total
In Parts per 100,000								
72·2	4·696	2·205	6·703	7·728	10·66	24·18	20·51	44·69
In Grains per Gallon								
50·54	3·287	1·543	4·692	5·410	7·462	16·926	14·357	31·283

the remainder being water.

Since the date when the above-mentioned table was compiled it has been discovered that a part of the solid matters formerly supposed to be in solution is in reality in a state intermediate between solution and suspension. These matters are known as "colloids" and they are particles of a jelly-like character; the purification of the colloidal matters has been one of the most difficult problems in sewage treatment.

Bacteria. Sewage is highly charged with various kinds of bacteria, some of which, as we shall see later, are made use of in certain processes of purification. It is therefore well to consider, at the outset, what bacteria really are.

Bacteria are minute vegetable growths, varying in size from about one-fifteen-thousandth to one-twenty-five-thousandth of an inch in diameter; they increase usually by division, occasionally by spore formation; their multiplication is exceedingly rapid and is interfered with by cold. Moisture is necessary for their successful working.

Classes of Bacteria. They fall into two classes, namely, the parasitic, needing a living host, and the saprophytic, living on dead matter, but some exist indifferently as both parasites and saprophytes. We have to deal with the saprophytic organisms, which are subdivided into anaerobic, living without air, and aerobic bacteria, living with air.

Crude sewage contains enormous quantities of anaerobic bacteria and relatively very few aerobic, but it is possible largely to destroy the former and to cause the latter to multiply, by prolonged aeration of the sewage. The effect of anaerobic bacteria is to cause the sewage to decompose, in which process part of the organic solids will be liquefied and gasified. The effect of aerobic bacteria is to enable the organic matters to combine with the oxygen present in the sewage and so to form harmless compounds, such as nitrates. The quantity of nitrates present in a sewage effluent is indeed an indication of the amount of purification by oxidation that has occurred in the treatment. It is, however, no indication of whether the effluent is fit to be discharged into a stream, for its fitness depends not on how much purification has been done, but on how much is left undone. A good criterion of this is the amount of oxygen which will be absorbed by a sample in a certain standard time, from a standard solution of potassium permanganate.

It is difficult to define the meaning of the word "harmless" as used in Section 3 of the Rivers Pollution Prevention Act, 1876. The old Local Government Board was often asked to prescribe a standard of purity for sewage effluents. The Board, however, always refused to do so, on the ground that each case should be dealt with on its own particular merits.

Investigations into Disposal 50 Years Back. In 1898 a Royal Commission was appointed to investigate the whole question of sewage disposal, and this Commission issued many reports. The eighth, issued at the end of the year 1912, deals with the question of standards of purity of effluents.

A brief summary of the conclusions of the Commission on this point is as follows:

"The law should be altered, so that a person, discharging sewage matter into a stream, shall not be deemed to have committed an offence under the Rivers Pollution Prevention Act, 1876, if the sewage matter is discharged in a form which satisfies the requirements of the prescribed standard, the standard being either the general standard, or a special standard which shall be higher or lower than the general standard, as local circumstances require or permit.

"An effluent, in order to comply with the general standard, must not contain, as discharged, more than three parts per 100,000 of suspended matter and, with its suspended matters included, must not take up, at 65° F., more than two parts per 100,000 of dissolved oxygen in five days. This general standard should be prescribed either by Statute or by Order of a Central Authority, and should be subject to modifications by that authority after an interval of not less than ten years.

"In fixing any special standard, the dilution afforded by the stream is the chief factor to be considered. If the dilution is very low, it may be necessary for the Central Authority, either on its own initiative or on application of the Rivers Board, to prescribe a specially stringent standard, which should also remain in force for a period of not less than ten years.

"If the dilution is very great, the standard may, with the approval of the Central Authority, be relaxed or suspended altogether. Relaxed standards should be subject to revision at periods to be fixed by the Central Authority, and the periods should be shorter than those prescribed for the general or for the more stringent standards.

"With a dilution of over 500 volumes, all tests might be dispensed with, and crude sewage discharged, subject to such conditions as to the provision of screens and detritus tanks as might appear necessary to the Central Authority."

Since that day, much research has taken place and quite a number of statutes (some of which will be referred to in Chapter XVI) have been added to our legislation.

Prevention of River Pollution. The Rivers Boards Act recently passed divides the country into areas, each under the care of its own local River Board. The last Rivers (Prevention of Pollution) Act (1951), gives these river boards the duty of making by-laws and determining standards of purity of sewage effluent which may be discharged into the rivers in their several areas (sec. 5). These standards vary from area to area, so no national standard of purity exists and river boards are guided mainly by the character of the rivers in their charge.

Insufficiently purified sewage effluent discharged into a river increases the proportion of organic matter, the number of bacteria and the number of parts of dissolved oxygen per 100,000 parts of water in the river. The bacteria and other micro-organisms (apart from their power to propagate disease if allowed to contaminate drinking water), use for their living processes some of the oxygen held by the water. The amount of oxygen so utilised

or absorbed is generally referred to as the "Biological Oxygen Demand" (or B.O.D.). A well-purified sewage effluent should give a B.O.D. value of 0·5 parts per 100,000 or less, and most sewage works managers try to maintain a standard of sewage effluent not exceeding 2 parts per 100,000, which, when taken into the stream of a river with a reasonable volume and velocity of flow, will dilute down to safe conditions for fish life and for the tiny animal or vegetable organisms which form the food of the fish. This standard of B.O.D. is also a good indication of the number of bacteria likely to be found in the effluent and so, indirectly, of its effect on the river as a source of domestic water supply.

The whole question of sewage disposal is one in which there has been a vast amount of experimental work going on for years, and is one of the greatest importance to the public at large. The prompt and effectual removal of the excremental and other refuse from the midst of our communities is of the utmost importance, but no one system of disposal can be applied indiscriminately, and the system which is applicable to one district may not be by any means the best for another, differently situated or conditioned.

Chief Classes of Disposal Methods. Broadly, the chief methods of treatment for the disposal of sewage may be classified so:

1. Discharge into the sea or a tidal estuary.
2. Land treatment (aerobic).
3. Some suitable combination of any of the following:

(*a*) Sedimentation tanks, with or without the use of chemical precipitants (mechanical treatment).

(*b*) Septic tanks or hydrolytic tanks (anaerobic treatment).

(*c*) Activated sludge tanks (aerobic).

(*d*) Contact beds or percolating filters (aerobic).

Objectives to be Aimed at. No matter what treatment is adopted, the primary object is purification. Sewage works should be kept free from nuisance; the production of sludge, or sewage mud, must be avoided as far as possible, if there is difficulty in getting rid of it; and lastly, the expenditure, both capital and annual, should be kept as low as possible consistent with efficiency.

Discharge into Sea or Tidal Estuary. In the case of towns on the sea-coast, discharge into the sea or a tidal estuary furnishes an efficient and economical means of disposal. Great care is necessary in selecting the position for the outfall, and careful observations of the nature of the prevailing currents should be made over a fairly large area. The observations are made with the help of floats, the directions taken being carefully recorded

with the aid of a theodolite or prismatic compass, so that the course of the current may be plotted on a plan. The sewage will in most cases have to be discharged into favourable currents on the ebb tide, tanks, of course, being provided for storage during high tide. In a few exceptional cases it is possible to discharge the sewage at all states of the tide without causing a nuisance, in which cases storage tanks are unnecessary.

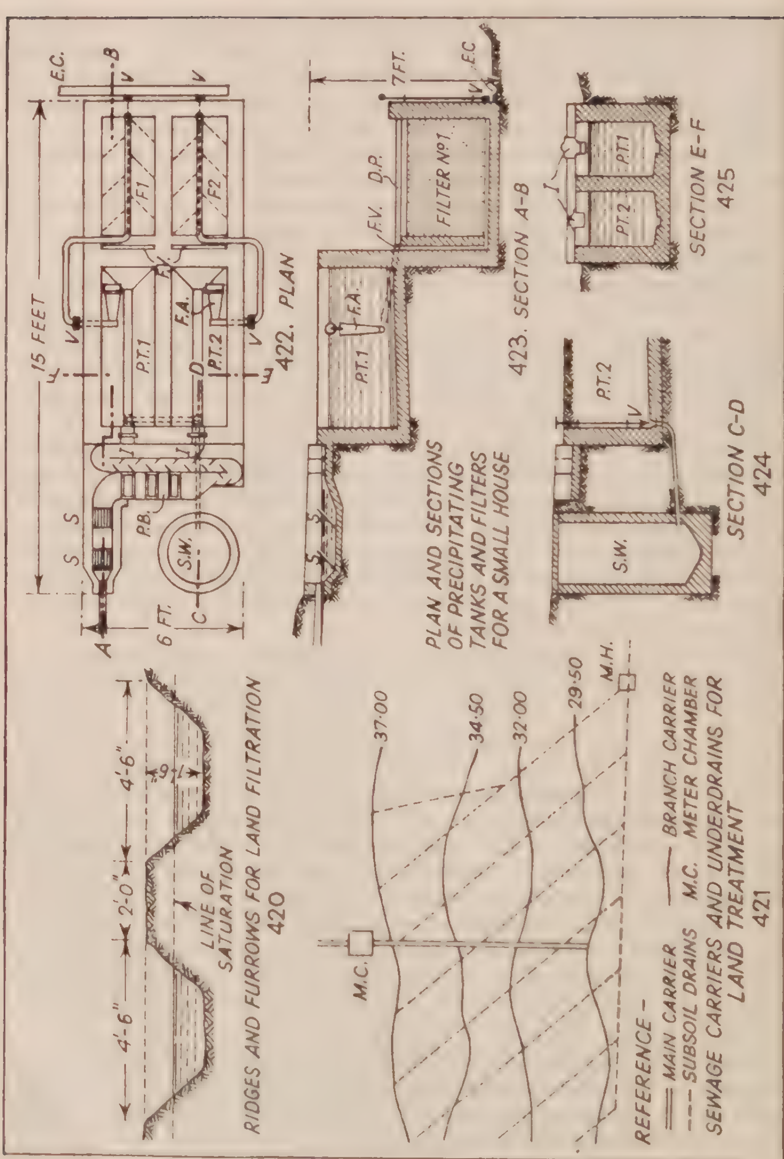
Land Treatment. There are two methods of applying sewage to land for the purpose of purification, known as irrigation and filtration respectively.

Irrigation. Irrigation is the system in which the sewage is made to flow over an area of land continuously for a certain time, the area being then rested while agricultural operations proceed. The land is not underdrained. This system is best carried out by using land which has a fall of about 1 in 100 and passing the sewage over it in a thin sheet.

Land Filtration. On the other hand, filtration is generally carried out by using flat land or levelling the plots, underdraining them, enclosing them with earth walls or banks, flooding the area with sewage, and allowing it to soak away, thus passing alternate layers of sewage and air through the soil. In both systems ridges and furrows, as shown in Fig. 420, are sometimes used, the advantage being that the roots of the crops absorb the sewage without the crops themselves being fouled.

The sewage carriers require to be carefully arranged and constructed. The main carriers or channels can be of concrete, and the minor carriers can either be similarly constructed, or may consist of grips, or channels, just cut in the ground. Fig. 421 shows what is known as the catch-water system, applied to an area of rough and irregular surface. The minor carriers are carefully formed along contours, at vertical intervals of about 2 feet 6 inches, as shown. The inlet to the main carrier is controlled by a meter chamber, to measure the quantity applied at one time. The entrance to the minor carrier, at its junction with the main, is controlled by a small sluice. The land drains should not be of less diameter than 3 inches, and there is no advantage in putting them deeper than from 4 to 5 feet below the surface. A manhole is shown on the subsoil drain, for the purpose of sampling the effluent passing through the drains.

Nature of Soil needed for Successful Land Filtration. A most important point in reference to the filtration treatment through land is the nature of the soil. A good loamy soil is the best, and clay or peat about the worst. Sand or gravel are of little use for



422. PLAN

423. SECTION A-B

SECTION C-D 424

SECTION E-F 425

PLAN AND SECTIONS OF PRECIPITATING TANKS AND FILTERS FOR A SMALL HOUSE

RIDGES AND FURROWS FOR LAND FILTRATION 420

SEWAGE CARRIERS AND UNDERDRAINS FOR LAND TREATMENT 421

the purpose, but peat and clay should only be used when there is a fair amount of vegetable soil above them, of at least 6 or 9 inches in depth. Good soils for purification purposes are alluvial drift and gravel, oolitic limestone, Bunter sandstone, magnesian limestone, chalk and old red sandstone.

Importance of Top Soil. The bulk of the purification is effected in the first foot or so of depth, but it is necessary to have an underlying soil of a porous nature in order to carry off the effluent. The action of an earth filter is partly mechanical, partly chemical and partly biological. The destruction of organic impurities in sewage is brought about by a process of active fermentation, termed nitrification, caused by aerobic bacteria, the organic matters being resolved into soluble nitrates, products having no smell, colour or injurious properties. Nitrification ceases if the treatment of the land with sewage is not conducted intermittently and, if irrigation or filtration is carried on without care and without regard to the scientific principles involved, there is a risk of the pollution of subsoil waters and streams.

It is easy to see why a non-porous soil is unsuitable for sewage purification—although the sewage may be mechanically strained, the absence of free oxygen in the soil prevents purification.

Given a suitable soil and good management, filtration through land will result in an effluent as pure as can be obtained by any other means; it must not be forgotten, however, that a sewage farm cannot be free from smell and should therefore not be near built-up areas.

Interchange in Land Treatment. It is a very general practice now to work a sewage farm on the principle of one section being given up to irrigation and another to filtration, and to change them over once a year. This enables the land to be well worked up and aerated, especially if the ridge and furrow system is adopted, and the ridges and furrows levelled once a year. Italian rye grass is a favourite crop on sewage farms, the reason being that it grows so rapidly and closely that weeds are kept down—an important point in land treatment. Mangolds and other crops are also grown.

It will be obvious that, if the areas are interchangeable for both irrigation and filtration, the whole must be underdrained.

That no hard-and-fast rule, or definite figure, can be given as to the area required for any particular case of land treatment will be evident from the following extract from the Fourth Report of the Royal Commission on Sewage Disposal: "We doubt whether the most suitable kinds of soil, worked as a filtration farm, should

be called upon to treat more than 30,000 to 60,000 gallons per acre per twenty-four hours at a given time (750 to 1500 people per acre), or more than 10,000 to 20,000 gallons per acre per twenty-four hours calculated on the total area of irrigation (250 to 500 people per acre). Soil not so well suited, worked as surface irrigation, or combined surface irrigation and filtration, 25 to 50 persons per acre." The sewage in the foregoing cases is assumed to have been settled in tanks before it is applied to land.

It is impossible to lay down any hard-and-fast rule as regards the proper proportions between the area being irrigated at one time and the surplus resting or aerating, but the Commissioners suggested that four-fifths of a surface irrigation farm and two-thirds of a filtration farm, should be at rest. The Commissioners in effect also expressed their inability to say whether slow or rapid alternations of work and rest are advisable.

The Commissioners laid much stress on the fact that the success or failure of a sewage farm lies largely with the management, and pointed out that there is much temptation to try and grow remunerative crops, that the farming operations should be relegated to the background, and the production of a good effluent come before everything else.

"Standby" Filter for Sewage Farms. When land treatment is adopted it is usually advisable to have a filter, such as will be dealt with later, as a standby for emergency; if one is provided it should be given a dose of sewage regularly to keep it in good condition. It is also the practice, before applying sewage to land, to pass it through screens, and often through sedimentation tanks as well. These will next be described.

Sewage "Screens". Various things, such as road metal, rags, brushes, corks, etc., find their way into sewage, and it is desirable in all cases (except in very small plants), whatever the nature of the subsequent treatment, to remove them by screening. There are many forms of screen, the commonest form consisting of a framework carrying a series of flat bars at intervals of about ½ to ¾ of an inch, the screen being inclined at an angle of 30° or more to the vertical and the bars bent over at the top in the direction of the sewage flow. The screen is kept clear by frequent raking, either by hand or machine. In large works mechanical devices are almost always used for keeping the screens clear. Where the screens are at a good depth below the ground, they are generally in duplicate, sliding vertically, so that they can be readily raised and cleaned. Other forms of screen are endless bands of copper-wire netting, and circular, revolving, perforated plates.

The screenings should frequently be removed, covered with lime or ashes, as they are often offensive, allowed to drain and dug into land or used as manure.

Screens should not be installed in very small works, such as those for a country-house, or a group of houses, as they need frequent attention or else will become completely blocked.

Methods Other than Land Treatment. Turning now to ways of treating sewage other than land treatment, I shall first describe the methods which were formerly in general use, and which are still largely employed to-day, after which a description will be given of a more recent development, the "activated sludge" method, which cannot economically be used except on works of some size.

Early Methods. The earlier methods still in common use fall into two stages: (1) the removal of suspended solids, by sedimentation or digestion, and (2) the oxidation of organic matters.

Detritus Tanks. Some of the suspended solids are inorganic, i.e. of mineral origin; these will settle more rapidly than the organic matters and therefore can be separated by passing the sewage through a tank, at a velocity sufficiently great to prevent organic substances from settling, but low enough to enable grit to be deposited. For this purpose the velocity should be about 1 foot per second. These tanks are called "Detritus Tanks" or "Grit Chambers". They should be long and shallow and there must be at least two of them, to enable them to be cleaned out in turn. They can be constructed of concrete and their floors should slope toward the inlet, at which end the greater part of the grit will be deposited. The combined capacity, of the two or more tanks provided, should be about half-an-hour's dry weather flow.

The reason for the removal of the mineral matter is that subsequent treatment is thereby facilitated.

There is some difference of opinion as to whether grit chambers should be placed before the screens or after; it is probably the better plan for them to precede the screens.

Settling Tanks. Sedimentation or Settling Tanks differ from the above in that they are intended for the purpose of settling the organic solids. The velocity of flow through them must therefore be very low. They may be worked on a continuous or intermittent principle; that is to say, the sewage may flow continuously through them at an imperceptible velocity, or they may be filled and allowed to stand for a time before being emptied; the only disadvantages of the latter method are that it involves a fall in level from inlet to outlet equal to the depth of the tank, and that more attention is required; the advantage is that a clearer effluent is

obtained. To facilitate cleansing there should be at least three of such tanks, except in small works, where they may be in duplicate.

They can be built of concrete with floors sloping toward a sludge outlet; a usual depth is from 6 to 8 feet and the total capacity of the tanks (including spares) should be from ten to eighteen hours' dry weather flow.

Continuous-flow Settling Tanks. If the continuous-flow principle is adopted, the inlet and outlet can be weirs, about 6 inches from which are scum boards extending into the sewage for the whole length of the weir, to induce vertical movement and thus prevent the incoming sewage passing straight along the surface from the inlet to the outlet weir.

Intermittent-flow Settling Tanks. If the intermittent-flow principle is adopted the inlet can be a weir, but the outlet must be a telescopic pipe or a floating arm which falls as the tank is emptied. The sludge is removed from intermittent tanks at about every third emptying; in continuous flow tanks it is removed every few days in summer time, but less frequently during winter, the object always being to remove it before it becomes septic. Sludge can be removed, without emptying the tank, by opening the sludge outlet and allowing the pressure of the water above to force it down the sloping floor, the process sometimes being aided by squeegees, either hand-operated or mechanical.

Precipitation Tanks. There is no doubt that the precipitation of suspended solids is obtained more quickly and thoroughly by the use of certain chemicals.

One of the oldest methods is to add about 6 or 10 grains of lime per gallon of sewage, but more efficient precipitation is obtained by reducing the quantity of lime to something under 5 grains to the gallon and by subsequently adding from 5 to 15 grains of sulphate of alumina or sulphate of iron, or of a mixture of sulphate of alumina with iron and silica, known as "aluminoferric". The effect of lime and a sulphate, in forming a flocculent precipitate which, in settling, brings down with it the finest of suspended particles, has already been described in Chapter VI, in dealing with methods of water filtration.

The effluent from a chemical precipitation tank will be clear and free from smell, but in no sense are the organic matters in solution purified; such an effluent, therefore, if passed into a stream, may later decompose and give rise to a nuisance; the effluent ought, therefore, to be subjected to further treatment before being passed into a stream. A further disadvantage of the method is the large

quantity of sludge produced, which needs frequent removal and is difficult to dispose of. This sludge is a mixture of 5 to 10 per cent. of solids and 95 to 90 per cent. of water.

Chemical Treatment. Chemical treatment was much used during the latter part of the nineteenth century; it is now seldom used except for sewage of a special character, as where it contains a large amount of waste from breweries and tanneries, in which case the chemicals may be of particular value in keeping down smell at the disposal works.

The construction of tanks generally used for chemical precipitation will in no way differ from those used for ordinary sedimentation, the process being either on the continuous or intermittent principle.

Horizontal- and Vertical-flow Precipitation Tanks. Settlement tanks, whether chemicals are used or not, are not invariably of the "horizontal-flow" type described above, in which the sewage flows from an inlet at one end to an outlet at the other. Sometimes a "vertical-flow" type is used. These are square or circular in plan and often as deep as 30 feet. The upper part has vertical sides, but the lower part is an inverted pyramid or cone converging to a sludge outlet at the bottom. The sewage is admitted low down in the tank, but just above the highest sludge level. The outlet is a weir at the top; this may extend around the whole perimeter of the tank. After admission the sewage rises very slowly, but the sludge carried in it will come to a stop and then start to fall to the sludge outlet. If a place for its deposit is available below the level of the outlet the sludge can be disposed of, without the tank being emptied, by opening the valve controlling the sludge outlet and allowing the hydrostatic pressure of the overlying sewage to force the sludge along an outlet pipe. As, however, a fall as great as the depth of the tank is seldom available, the sludge usually has to be pumped from the outlet pipe to a higher level.

Dortmund Tanks. Vertical-flow tanks can be of smaller capacity than horizontal-flow tanks, but their great depth makes them more costly to construct. They are often called Dortmund tanks, as they were first made at the town of Dortmund in Germany. They are illustrated in Fig. 426.

Septic Tanks. Septic tanks, first introduced by Mr. Cameron at Exeter, resemble sedimentation tanks in that their purpose is to get rid of solids in suspension, which solids are deleterious to the working of bacteria beds. Unlike sedimentation tanks, however, the intention is to liquefy or gasify the suspended solids as far as possible, rather than to remove them as sludge. With this object

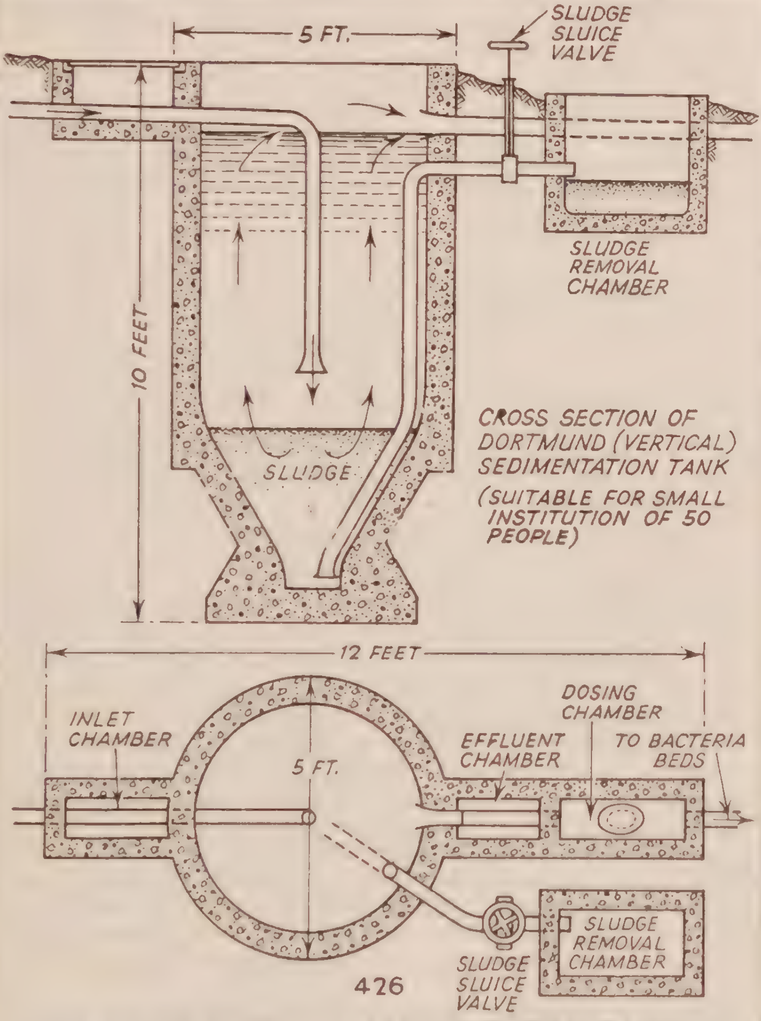
the sludge is left in the tank until it putrefies, a portion only of it being removed when it has accumulated to such an extent as to fill the tank to about one-third of its capacity. At least three tanks should be provided, except on small works, and the capacity of all the septic tanks provided should be about twenty-four hours' dry weather flow. Their depth is usually about 10 feet.

The inlet may be by a weir with scum board, or by a vertical inlet pipe carried down to about half the depth of the tank. The outlet is usually by a weir provided with a scum board.

Anaerobic Action in Septic Tanks. The action of septic tanks depends upon the sludge being left long enough on the bottom for all air to escape, so that the anaerobic bacteria thrive and cause decomposition. Bubbles of gas then come through to the surface, carrying solid particles with them, thus forming a scum which helps to keep air from direct contact with the sewage. The decomposition, in addition, liquefies some of the solids and breaks up the remainder into fine particles. At one time it was thought necessary to roof in these tanks, in order to preserve the anaerobes from light and air; it is, however, now known that this is effectively done by the scum, so that the cost of a roof can be avoided unless it is necessary to prevent a nuisance from smell.

As compared with sedimentation tanks, septic tanks have the advantage that much less sludge has to be disposed of, and this will, if well digested, be far less offensive then the raw sludge from settling tanks; further, it contains a much smaller proportion of water, so that it is more easily dealt with and more useful as manure. Their disadvantages are, firstly, that the ebullition of gases liberated from the sludge carries particles of sludge upwards, so that the effluent contains large numbers of suspended black particles, which need to be settled in an additional settling chamber before it is passed into bacteria beds; secondly, the effluent contains a great deal of carbon dioxide and practically no oxygen, a state which is unfavourable to subsequent aerobic treatment, so that it is advisable to aerate it by allowing it to fall from a trough into channels, if the necessary fall is available; a third disadvantage is the objectionable smell which arises from these tanks. They are seldom installed now in any large new plants, but they are the most popular type for isolated country houses owing to the small attention needed.

Hydrolytic Tanks. An improved form of septic tank, known as a hydrolytic tank, was introduced by Dr. Travis at Hampton. He was the first to realise that a large part of the solids in sewage were of "colloidal" or jelly-like character, and that these, though



426

PLAN OF DORTMUND SEDIMENTATION TANK

SHOWING ARRANGEMENTS FOR SLUDGE REMOVAL AND DOSING CHAMBER LEADING TO CONTACT BEDS OR CONTINUOUS FILTERS

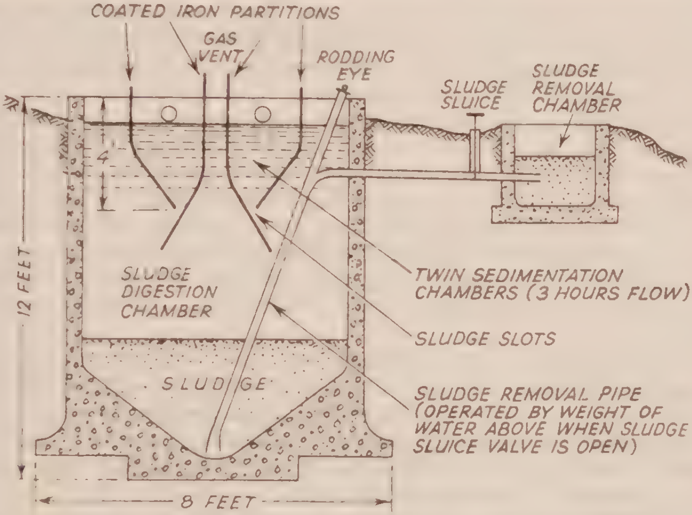
not ordinarily deposited in sedimentation or septic tanks, could be made to settle if the sewage was brought into contact with a sufficient area of solid surfaces.

Use of Colloiders. He therefore divided his tanks into compartments. The sewage was first admitted to settlement compartments in which were fixed a large number of vertical splines, or strips of wood, known as colloiders, to which colloids and fine suspended particles adhered, to drop off subsequently in flakes to the bottom of the chamber. A further innovation was that this falling mass gravitated through outlets to a liquefying chamber, in which the decomposition took place. The rising sludge particles, carried by the gases of decomposition, could not get into the settlement compartments, the effluent from which was therefore remarkably free from suspended solids and colloids. This effluent passed over weirs from the settlement compartments for subsequent aerobic treatment, whilst the sewage from the liquefying chamber, containing a large amount of sludge particles, was passed over a separate weir to a hydrolysing chamber; this was simply an additional settlement chamber fitted with colloiders.

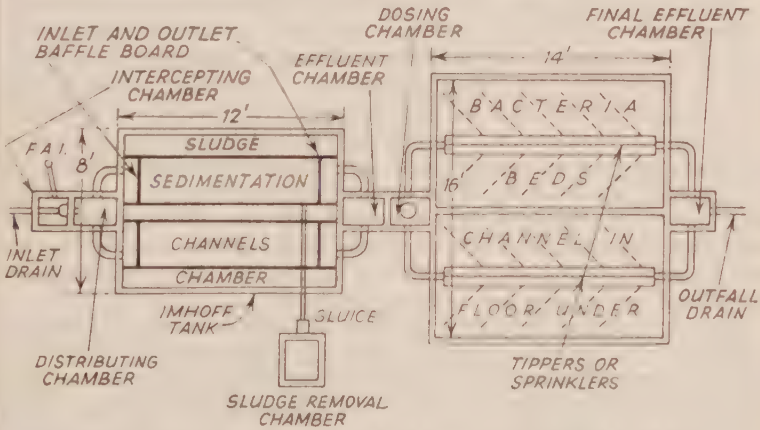
The Imhoff Tank. The Imhoff tank, largely used in Germany and America, works on the same principle as the Travis tank, but differs from it chiefly in that the main chamber (that for liquefying and digesting the sludge) has no outlet except that for sludge removal in the central sump. It receives the solid matter from the twin sedimentation chambers above, allowing it to digest and liquefy, only the residual sludge passing out, while the offensive gases which form pass out through the gas vent between the two sedimentation chambers, as will be seen in Fig. 427.

Need for Further Treatment of the Effluent. Before passing on to other methods of sewage treatment it should once more be emphasised that screens, detritus chambers, sedimentation tanks, chemical precipitation treatment, septic tanks, hydrolytic and Imhoff tanks are merely means of depositing or liquefying suspended solids, and hence clarifying the liquid and making it more suitable for subsequent purification. The effluent from these tanks contains large amounts of organic solids in solution, which, if not oxidised, will subsequently decompose and give rise to a nuisance.

Methods of Oxidation. It remains then to describe the methods in use for oxidising dissolved impurities. Land treatment is one such method, but this has already been described; other methods have to be used where it is desired to treat large volumes of sewage on a comparatively small site. Such treatment is carried out in



ENLARGED CROSS-SECTION OF IMHOFF SEDIMENTATION AND DIGESTION TANK



SMALLER SCALE PLAN IN DIAGRAM OF IMHOFF TANK AND FILTER BEDS
(SUITABLE FOR INSTITUTION OF 250)

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what are often called "bacteria beds". These may be on the intermittent principle, in which case they are called "contact beds", or on the continuous-flow principle, in which case they are called "percolating filters" or "trickling filters"; in either case the cause of purification is aerobic bacteria.

Bacteria Beds. The beds are filled with pieces of stone, clinker or similar material. Though rough porous materials are generally preferred to smooth impervious ones, quite good results are obtainable with the latter; in fact it may be said that the nature of the material is unimportant as long as it is clean and free from dust, is not so soft as to crumble, and contains no constituents which will cause it to disintegrate. Broken clinker is mostly used because it is usually cheaper than stone, but it is not so durable.

Aerobic Bacteria. Aerobic bacteria are not common in sewage, so that a new filter will give little or no purification. With repeated dosing and aeration, however, the aerobic bacteria will multiply and the anaerobic will perish, until in a few weeks or months, according to the temperature, the former will form into spongy growths on the clinker or stone.

Dibdin's Slate Beds. Contact beds were first used by Mr. Dibdin, then chemist to the London County Council, in 1893.

The submitting of an effluent to one contact bed only is termed a single contact process, and does not give a sufficiently high degree of purification. If the effluent is passed through two contact beds in succession, the process is known as double contact, which is the usual, and if through three beds, triple contact, which is unusual. A very common depth for contact beds is about 4 feet, but they range from about $2\frac{1}{2}$ to 6 feet. A very satisfactory discharge after each filling is about one-third of the gross capacity, the other two-thirds being occupied by the filtering medium, bacterial growths, deposits of solids and colloids and by water which never drains away. This is equivalent to a discharge of 56 gallons per cubic yard of filling material.

Two hours may be taken to fill a bed, after which the sewage is allowed to stand in it for one hour; alternatively filling can be done in one hour and two hours allowed for standing; in either case a further five hours is allowed for the effluent to drain away and for air to penetrate between the stones. The beds can therefore be filled three times in twenty-four hours, it being thus possible to deal with 168 gallons per cubic yard per day. As, however, the double contact process is generally used this is reduced to 84 gallons per cubic yard of their joint capacity.

Such a rate would be highly satisfactory and could not be kept up for long, unless the sewage is a weak one or the suspended solids have been removed, by chemical precipitation or a hydrolytic tank. A more usual rate is 40 to 50 gallons per cubic yard per day. Should it fall below the lower of these figures it is a sign that the beds have become unduly choked with solids through overwork.

If the beds are given a rest their capacity will be restored to a considerable degree, but sooner or later it will be necessary to take out the stone and wash it. Instances have been recorded where beds have worked for more than ten years satisfactorily without cleaning, but this can only be hoped for when the conditions are most favourable. A more usual period would be four or five years for the primary beds and seven or eight for the secondary.

Construction of Contact Beds. The floor and walls of the beds are usually built of concrete and must be watertight; the total area should be divided up so that the maximum size of a single bed does not exceed about two hours' dry weather flow, which ensures quick filling and emptying and satisfactory working generally. In the case of double contact, it is usual to place the second bed at such a level that the first bed can be readily discharged on to it. A finer material is used in the second than in the first, since the object of the first is to "take the rough off", so to speak. A common practice is from $1\frac{1}{2}$ to 2 inches gauge for the first beds, and $\frac{3}{4}$ to $1\frac{1}{2}$ inch for the second, although finer material is sometimes used.

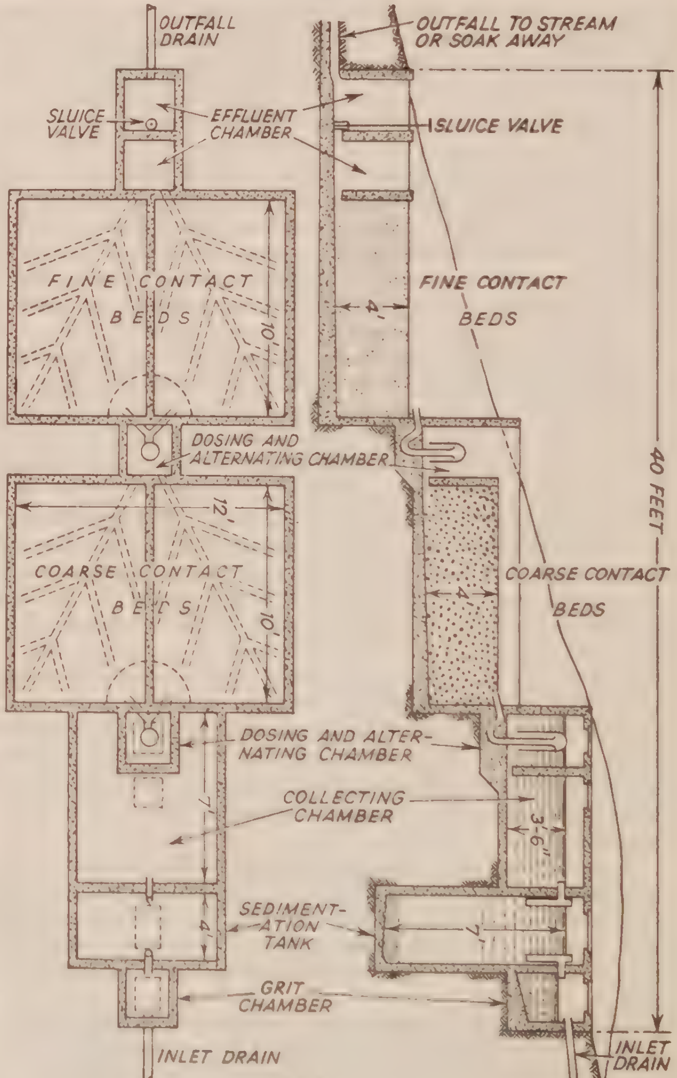
Beneath this material and on the concrete floor is a system of drains, of one of the following kinds:

1. Some form of false floor made of specially shaped tiles.
2. Semicircular channels in the floor, covered by tiles; these tiles are sometimes perforated, but it is a needless expense.
3. Semicircular tiles with perforations on the top or back of the semicircle.
4. Interlocking tiles forming drains in section like an inverted V.

In either case the drains are laid to fall to main effluent channels.

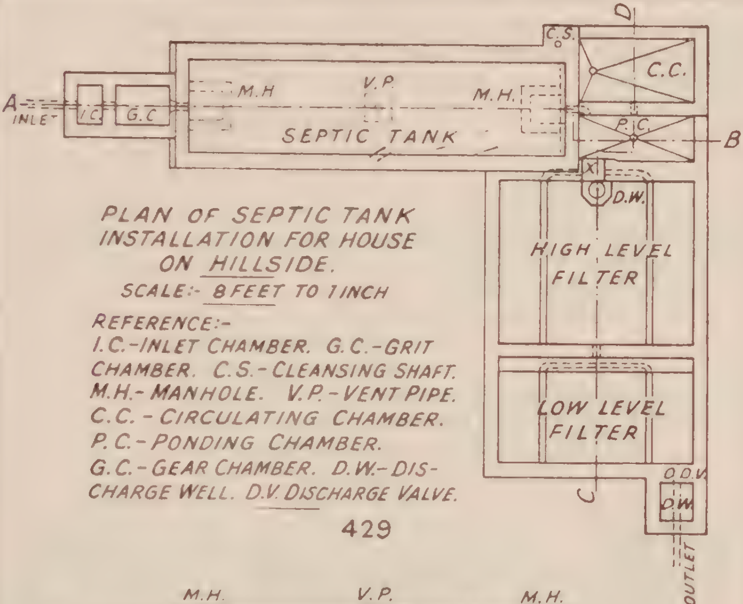
The inlets and outlets of contact beds are usually controlled by means of automatic gear, a description of which is beyond the scope of this introduction to the subject, but the general arrangement is shown on Fig. 428.

Construction and Working of Continuous Bacteria Beds. The percolating filter is distinctly different from the contact bed so far as the method of working is concerned. The outlet is allowed to remain open, and the tank liquid is applied usually in the form of



PLAN AND SECTION OF CONTACT BEDS — SUITABLE FOR A SMALL COMMUNITY OF ABOUT 100 PEOPLE, WITH APPROXIMATE DIMENSIONS.

428



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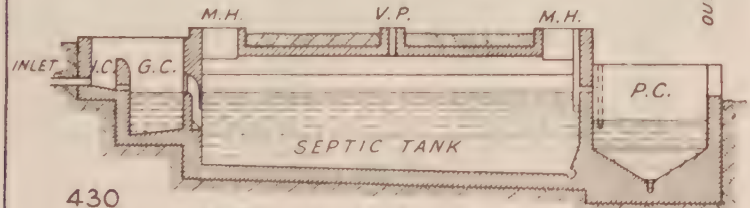

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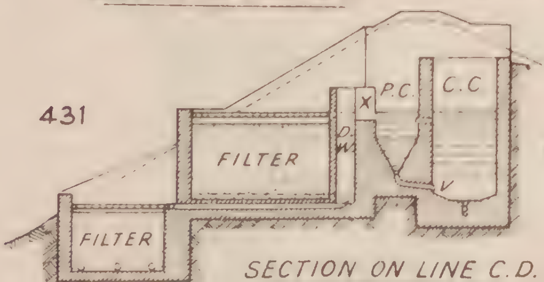
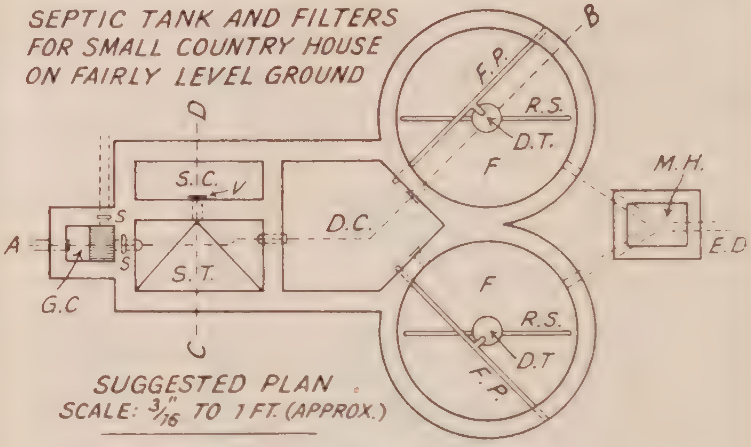
SECTION ON LINE A.B.

431



SECTION ON LINE C.D.



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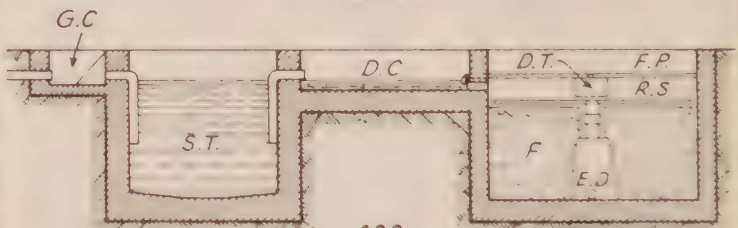
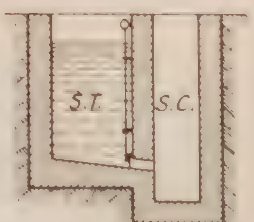


433
SECTION ON LINE A-B

434



SECTION C-D

a fine spray, by automatic or other means, so arranged that alternate layers of sewage and air pass through the filter. Such beds are usually circular or rectangular in plan, the construction being formed in much the same way, except that the treated effluent is allowed to flow away freely through an opening at floor level at the lower end. Since there is no hydrostatic pressure in the beds the walls need not be of watertight construction; they are, in fact, sometimes made honeycombed, with the idea of securing better aeration of the beds. It is, however, an undesirable proceeding, as it causes the beds to become unduly chilled in cold weather, in addition to which the holes in the walls become a breeding place for flies. The general arrangement can be seen, on a small scale, following the "Septic Tank" in Figs. 422 and 423.

It is important that the sewage shall be applied evenly to every part of the bed. For very small plants, such as one for a single house or institution, where economy is of great importance, this may be done sufficiently well by allowing the sewage to overflow from a large number of cast-iron troughs, or from W-shaped gutters with notches in their central ridge. For large plants, which are more likely to be used intensively, a more precise method is desirable and the following are examples which have been adopted:

1. Spraying under pressure into the air from nozzles in pipes fixed at or near the surface of the beds; the objection to this method is that the sewage spray may be blown a considerable distance in the air in stormy weather.

2. Allowing the sewage to trickle from holes or notches in the sides of moving pipes, this being the more common method.

Mechanical Distributors. In any case it is always possible for the pipes to be driven by motors, but it is obviously economical to allow the sewage to drive them, when there is head enough to give the requisite pressure.

Revolving Sprinklers. When the bed is circular in shape the pipes may be either two or four arms, radiating from a central column where they are fed with sewage. The holes in the pipes are closer together, or else of larger diameter, near the ends than nearer the centre, because they have a greater area to feed. The sewage, issuing from the holes in the side of the pipes on one side, exerts a reaction on the pipe, which drives it in the opposite direction, on the same principle as in the lawn sprinklers in common use. The pipes are of wrought-iron or steel and usually the holes are bushed with gunmetal or brass to prevent corrosion. Even then the holes tend to become choked at times with suspended solid particles, so that they require occasional clearing.

To avoid this trouble, sometimes the sewage is made to pass from wide notches in the feed tube into buckets of a long water-wheel, the weight of the sewage driving the wheel forward, the sewage itself being then spilled on to the bed. In other cases the water-wheels are quite short and spill their contents into perforated troughs from which the sewage trickles on the bed. In large beds usually the radial arms are steadied by supporting their extremities by wheels running on rails.

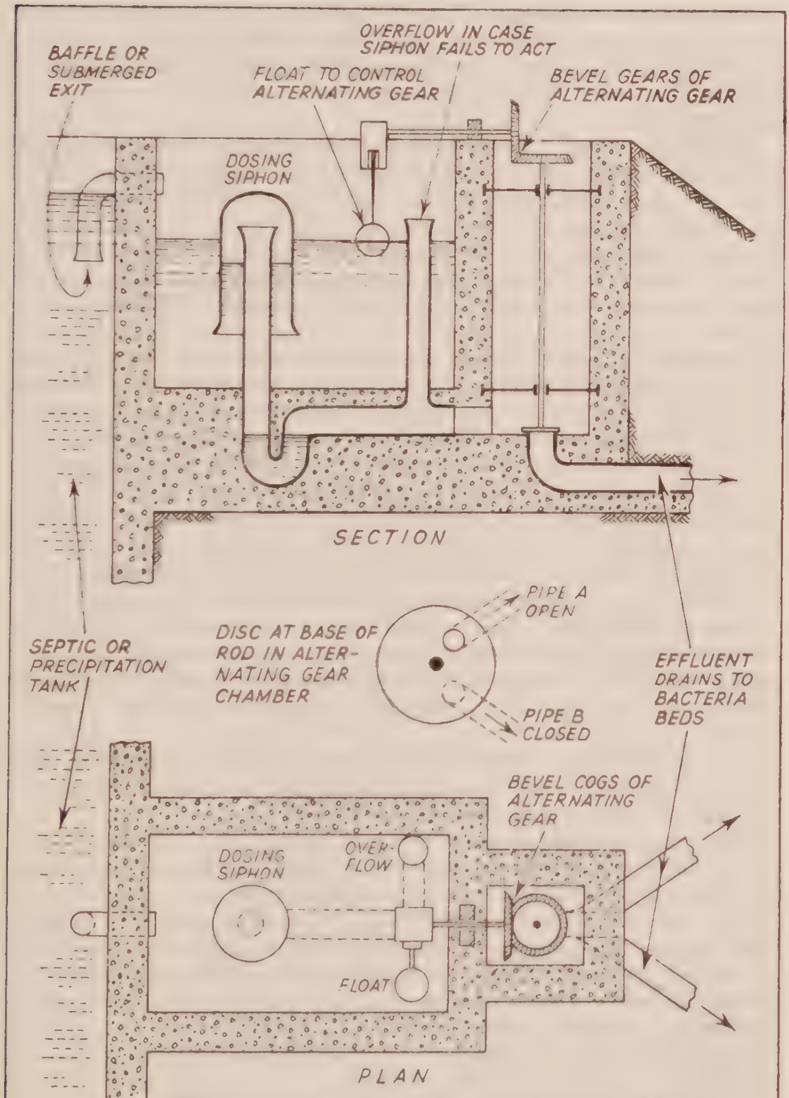
Distributors for Rectangular Beds. When the beds are rectangular the same principles can be adopted, but it is necessary for the distributors to be fed from troughs by siphons. Some of the most modern distributors for rectangular beds have water-wheels at their ends only, these discharging into pipes which span the bed. The direction of movement of the distributors has to be stopped and reversed when they reach the ends of the bed, which can be done quite simply by fixed buffers, which actuate levers.

The above description gives merely a general indication of the nature of the many automatic sprinklers produced by various manufacturers.

Dosing Chambers. Filters should work at about a constant rate for the best efficiency, and it must be borne in mind also that automatically operated distributors will not move at all unless they are fed with a certain minimum of sewage. It is usual therefore to provide a tank called a "dosing chamber", through which the sewage passes before reaching the filter. This will store up sewage when the flow is small and automatically discharge the whole of its contents when it becomes full. The filter will then work intermittently at its normal speed. As a certain amount of sedimentation will occur in the dosing chamber it should have a sludge outlet. It is illustrated in Fig. 435.

Depth of Bacteria Beds. There are differences of opinion as to the best depth for percolating filters, but 4 feet of material is essential and many authorities on the subject prefer from 6 to 10 feet. Deep filters obviously need less area for the same capacity and smaller distributors, so that they are less expensive, even when allowance is made for the extra cost of deep excavation. Deep filters involve, however, a big loss of head, since the sewage must go in at the top and out of the bottom.

Size of Filter-bed Material. The gauge of the filtering material is usually rather less than that commonly adopted for contact beds, from ¾ inch to 1 inch being fairly normal practice. There is, however, no unanimity of opinion as to the best gauge—in fact it is probable that the gauge should be regulated according to the



435. DOSING AND ALTERNATING CHAMBERS

nature of the sewage and of the preliminary treatment. a sewage which may have a quantity of suspended solids requiring a considerable depth of relatively coarse stone. and one which is fairly free from suspended solids and colloids having a less depth of finer material.

"Ponding" on the Surface of Bacteria Beds. It is sometimes found that gelatinous fungoid growths occur on the surface of the filters, so that ponding of the sewage occurs. This can generally be checked by resting the beds. If circumstances prevent the resting of the beds. or if this proves ineffectual. the addition of a dose of chlorine to the sewage may have the desired effect. A more drastic remedy is to apply caustic soda or copper sulphate to the growths.

A certain amount of fine suspended solids will usually pass through percolating filters, whilst colloidal matters. after collecting on the filtering medium, will periodically break away in flakes. usually in early spring. These solids may at times amount to more than the 3 parts per 100,000 which the Royal Commission on Sewage Disposal regarded as the limit which should be discharged into rivers. In works of size. therefore. a tank. called a "humus tank", is provided for their settlement. It contains about four hours' dry-weather flow and is like an ordinary sedimentation tank. except that the flow through it is more rapid.

Rate of Filtration. The general rate of filtration of a sewage of average strength, previously passed through settlement tanks or septic tanks, will be about 70 to 100 gallons per cubic yard of filter per day, which is about twice the rate of passing through contact beds.

Contact Beds and Percolating Filters Compared. The relative merits of contact beds and of percolating filters were summarised many years ago by Dr. Barwise as follows:

With contact beds the sewage need not be so carefully distributed. whereas with percolating filters the sewage must be carefully and intermittently distributed by expensive means.

With contact beds the size of the filtering medium need not be so carefully graded. whereas in the other case it needs careful grading.

Contact beds must have watertight walls. whereas percolating filters are often formed with walls of very open construction. often above ground. or with no walls at all.

Double contact is required to give results approaching that obtained from one percolating filter.

With contact beds the oxidation is limited. as the air supplied only equals the volume of sewage treated, while the air supplied

to percolating filters may be as much as five or six times the volume of sewage, thereby giving greater oxidation.

With contact beds the sewage, being stagnant, has a greater tendency to plug the bed up, while, in the other case, such little plugging as there is is on the surface, and the filter does not deteriorate if well made.

Lastly, percolating filters will do more work per day than can be done by contact beds of equal area.

For these reasons contact beds are now seldom installed.

Activated Sludge Process. Mention has already been made of the activated sludge process of sewage purification, a development of recent years. It is somewhat revolutionary in character, since it reverses the old idea of first removing suspended solids and then oxidising the dissolved impurities. In this process the dissolved impurities are oxidised first, the suspended matters being utilised in the process, for carrying aerobic bacteria about the whole bulk of the liquid; subsequently the suspended solids are removed by sedimentation.

For many years in the nineteenth century experiments were carried out by blowing air through sewage with the object of oxidising impurities. The results were invariably disappointing, owing to the difficulty of keeping the air in contact with the impurities long enough before it bubbled through and escaped.

Eventually Dr. G. J. Fowler discovered that if sludge is repeatedly aerated, the anaerobes, which are present in it in great abundance, are destroyed and aerobes take their place. Such sludge is then said to be "activated" because, if it is circulated in fine particles in sewage whilst air is being passed through it, the aerobes will bring the oxygen into chemical combination with the dissolved organic matters and nitrify them.

To get the best result the particles of sludge must be moved about in the sewage with a velocity of about $1\frac{1}{2}$ feet per second, and this movement is generally created by means of the air which is needed for oxidation. This is done in an aeration tank about 10 to 12 feet deep.

If the air were blown through nozzles or perforations it would rise quickly as bubbles and escape without doing much good. It is therefore forced by air compressors, or rotary blowers driven by an electric motor, through porous tiles, known as diffusers, which form part of the floor of the tank—generally about $\frac{1}{18}$th part of the whole floor. The air should preferably be filtered before it is drawn into the blowers, or particles of dust will gradually choke the diffusers, so that they will need occasional cleaning.

The ascending air drives up the liquid and sludge lying over the diffusers and eventually escapes from the surface, but the liquid and sludge move laterally to places where there is no rising column of liquid, the unsupported sludge then falling to the bottom of the tank once more. As more and more sludge accumulates in heaps in those parts of the floor where there are no diffusers, it slides down upon the diffusers and is blown up once more. During all this time sewage is flowing very slowly in and out of the tank, passing through the whirling particles of sludge in its passage. The sewage leaves the tank clear and inoffensive, carrying with it a large amount of the sludge particles. It is therefore passed into settling tanks, where it remains for one-and-a-half to four hours. A part of the settled sludge is returned to the sewage, at its inlet to the aeration tank, to replace that which has been carried away in the effluent. It appears that the amount of sludge in the aeration tank should be about 7 per cent. of the volume of the tank.

It has been pointed out that the amount of air actually utilised in oxidation is only about 5 per cent. of the air admitted, the remainder being required only for the purpose of agitating the sludge. The question naturally arose as to whether some cheaper method of agitating the sludge and of aerating the liquid could be devised.

It has been shown by Mr. Haworth at Sheffield that the activated sludge process can be carried out, without the introduction of compressed air, by passing the sewage along a channel while the surface is churned up by paddles, or even disturbed by giving the channel a slight slope, the sludge being given a spiral movement by putting baffle walls in the centre of the channel at an angle to the direction of flow.

Advantages of Activated Sludge Process. The advantages of activated sludge treatment are as follows:

It requires little space, causes remarkably little smell, and it is a very flexible form of treatment, for the time of aeration, quantity of air and proportion of sludge can all be varied to give the desired result.

Its disadvantages are that working costs are higher than those of sedimentation and filtration works, that skilled management must be in attendance, that it is very sensitive to changes in the character of the sewage and that enormous quantities of sludge are produced. It may also be mentioned that occasionally there is a sudden increase in the sludge in the aeration tank to more than twice its normal volume, and that this is accompanied by a deterioration of the effluent. This is known as "bulking" and is

due to presence of protozoa and other growths, brought about apparently by insufficiency of air. It can be remedied by prolonged aeration.

A most noteworthy fact, in the activated sludge process, is the rapidity with which organic matters are oxidised when the sewage is first brought into contact with the sludge and the slowness with which it is improved by more prolonged treatment. For example, at Birmingham it was found that 60 per cent. of the impurities were oxidised in one hour and that only a further 32 per cent. were oxidised in the next five hours.

It seems therefore that, although it is possible to effect satisfactory purification by sufficiently prolonged activated sludge treatment and settlement alone, it is more economical to aerate for about one hour only and to complete the oxidation of organic matters in percolating filters. After the one hour's aeration and subsequent settlement of sludge, the sewage will be quite free from colloidal matters and well charged with oxygen, and can be passed through the percolating filters at twice the ordinary rate. When this arrangement is adopted it is, however, necessary to reactivate the settled sludge, before returning it to the sewage entering the aeration tanks, since the sludge has more work to do, as it were, when it is brought into contact with fresh sewage every hour, than it would be required to perform if it worked on the same sewage for six or eight hours, which would be about the time required for full purification.

The activated sludge is not well adapted to small plants.

Disposal of Sludge. One of the greatest troubles in sewage disposal works of any size is the disposal of sludge. Formerly it was sometimes possible to dispose of it in a crude state by sale as manure, but this is now practically impossible and the problem is to get rid of it at the least possible cost. The principal methods are as follows:

1. Barging it out to sea—a cheap process for places conveniently situate for so doing. This is done in the case of London, Manchester, Southampton and other places.

2. Covering flat land with a layer of a few inches of the wet sludge. This rapidly dries, but the system is unsuitable for strongly smelling sludge.

3. Shallow burial in the ground. Wet sludge is run into trenches about 24 to 30 inches wide and 12 to 18 inches deep, spaced about 3 feet apart. When the sludge has dried to a firm state it is covered with a thin layer of soil. After a period of not less than one month the land is ploughed up and planted with crops. Land

should not be sludged in this way more than once a year. The objection to the method, in large works, is the very great area of land needed.

4. Lagooning or air drying. In this method earth tanks, from 2 to 4 feet deep, are made by excavation and by forming banks with the excavated material, and under-drained with 3 inch or 4 inch diameter agricultural land drains, spaced at intervals of about 9 feet. The bottom of the tank is then covered with a layer of 6 inches or more of clinker or ashes. Sludge is then run in, or pumped in, and allowed to remain there for some months. When moisture has drained and evaporated sufficiently for digging out, it will be found to have shrunk to about one-half its original volume. When dug out the sludge may be used as manure, or for filling up low-lying land. The objection to the method is the nuisance which arises from smell and flies, so that it should not be used near inhabited areas. Its advantages is its cheapness as compared with most other methods.

5. Pressing it into cakes in special presses. This process reduces moisture content to about 50 per cent. and the bulk to about one-fifth. If the district is agricultural the cakes may be saleable; in other cases they are used for filling low land, dug into land, barged to sea or mixed with house refuse and burnt in refuse destructors. This is an excellent method of treatment, but unfortunately it is a very expensive one.

6. By digestion in tanks. This is a process which has been developed greatly in recent years at Birmingham and elsewhere. It is a septic tank treatment applied to sludge after its separation from sewage, the sludge being usually inoculated by an admixture of already digested sludge.

Sludge Digestion. The digestion or decomposition is usually carried on in two stages, in primary and secondary digestion tanks. In the first, it is kept only so long as it is digesting vigorously and evolving gas, the process being aided by maintaining a temperature of about 75° F.; the gas given off in this stage can be used to drive gas engines, as it has a far higher calorific value than town gas. The sludge is then passed to secondary tanks, where a certain amount of liquefaction occurs, the liquid given off being taken away and returned to the raw sewage for treatment. The final sludge, which is inert and unobjectionable, is pumped to drying beds which are under-drained, and is later dug out and disposed of by sale or for filling land. At Birmingham the process is carried on near thickly populated areas, there being practically no smell. Perhaps the first example in the country of the activated sludge

process is carried out in the West Middlesex Sewage Disposal Scheme at Mogden about ten miles west of London. There is a ready sale for the digested sludge as a fertiliser and the sludge-gas which is produced, first used for power production on the works, has been found to have valuable industrial uses, and is now compressed into gas cylinders and sold to firms like Fords at Dagenham with a saving in the county rates, while the machinery on the works has gone back to diesel oil, petrol, etc., on the score of economy.

Disposal Schemes for Country Houses without Main Drainage. One or two examples of small installations may now be given for the disposal of the sewage of country houses, or small institutions which are not connected to public sewers. Figs. 422–425 show details of a chemical precipitation system. Fig. 422 shows a plan of the scheme. The overall dimensions indicated are approximate but they give a rough idea of the scale. The sewage enters at A and passes through two screens; it then passes along an iron channel containing three precipitating boxes or cages, P.B., containing, say, blocks of alumino-ferric. It passes along a further length of channel, in which are a series of baffle plates to mix thoroughly the precipitant with the sewage, which then enters, through either of two inlets, I., precipitating tanks, P.T.1 or P.T.2. The effluent from these is conveyed by floating arms, F.A., to distributing pipes lying over the centres of the filters. Each filter is ventilated by a filter vent, F.V., and the effluent passes down through the filter and out through a valve, V., into the effluent channel, E.C. The sludge from the precipitating tanks passes to a sludge well, S.W., the entrance to which is controlled by the valve, V., shown in Fig. 424. The inlets to the precipitating tanks are in the form of sluices, shown in Fig. 422, that of the precipitating tank, P.T.2 being shown closed and that of P.T.1 being shown open. The sludge can be removed from the sludge well by means of an ordinary farmyard or chain pump and conveyed to the kitchen garden by a trough or channel. If the garden is small, it may be better to transport the sludge in a water barrow and to empty it into shallow trenches, 12 to 18 inches deep. These can be topped over with garden soil as soon as the sludge is able to take it. The soil bacteria will then quickly transform the sludge into fertile plant food.

Chlorine Treatment to Prevent Odour and Stop "Ponding" of Filter Beds. If the disposal plant has to be rather near the house and on the side of the prevailing winds, there may be some noticeable odour at the house or in the grounds nearby and if the plant cannot be placed farther away and on the side where prevailing

breezes will carry such odours away rather than to the house, it may be worth while to install an automatic chlorination equipment. An expert in chlorination should be consulted, for overdosing would kill off the bacteria and stop the bacterial action, but correct dosing (either in liquid or gaseous form or as sodium hypochlorite and bleaching powder) reduces odour without interfering with the bacterial action. It also helps to keep the filtering material in a clean condition and prevents the film of green slime (due to algae) on the surface of the filter beds, holding up the effluent in large puddles (or ponds), and allowing the effluent to run too fast through the filter bed in the remaining parts which are not so affected. Public sewage-disposal plants sometimes cure this tendency of the filter beds to "pond up" by inoculating the surface with a few pieces of clinker from a nearby sewage works where the beds are known to be clear. This inoculation introduces a few specimens of a small grey-blue insect, known as a "springtail" (*Acherutes Viaticus*). These soon multiply and feed upon the algae, thus keeping the surface clean. In small bacteria beds for private houses, it is generally enough to rake over the surface occasionally.

Septic Tank Installations. In Figs. 429–431 a septic tank installation is shown, the system involving the use of a covered septic tank and successive filtration. Such a system is applicable to the case of a house on a hill-side, or any position in which a good fall is obtainable. The sewage enters at A, passing through the inlet chamber, I.C., and the grit chamber, G.[1]C.[1], from which it enters the septic tank. The tank, as shown in Fig. 430, is covered and ventilated, and has two manholes for access. Both inlet and outlet are submerged, and the sewage passes into the ponding chamber, P.C., from which it can circulate through the circulating chamber, C.C., as shown in Fig. 431. It will be noted that there are non-return valves, V.V., between the ponding and circulating chambers. From the ponding chamber the tank liquid passes into the automatic gear in the chamber X., and thence into two distributing pipes over the top of the high-level filter. The effluent from this filter is collected in drains on its floor, leading to the discharge well, D.W., adjoining the ponding chamber, and from there it is permitted to pass to the low-level filter, from which the final effluent is discharged into the nearest water-course. The sludge from the septic tank is collected through a special form of perforated pipe, and led to a cleansing shaft, C.S., the floor of the circulating chamber connecting with the same pipe. From the cleansing shaft the sludge can be led in any desired direction.

Smaller Installation for House on Flat Site. Figs. 432 to 434 show an example in which the site is rather flat, and the open tank can be put at such a distance from the house and road as not to permit of nuisance from smell.

The sewage enters a grit chamber, G.[1]C.[1], in which is a screen. From the grit chamber an overflow or emergency drain is shown in dotted lines, the entrance to it being controlled by a small sluice, S. The sewage passes from the grit chamber, past a sluice S, to the septic tank, S.T., the inlet being submerged. The floor of this falls, leading past a valve, V., to the sludge chamber, S.C., from which the sludge can be removed by pumping or other means. The outlet for the liquid from the septic tank is submerged, and leads to a distributing chamber, D.C., a very shallow chamber, as shown in Fig. 433.

Adjoining the distributing chamber are two filters, F., of circular plan. In the centre of each is a collecting or dosing tank, D.T., which actuates a rotary sprinkler, R.S. The dosing tank is fed from the distributing chamber by a feed pipe, F.P., and the chamber can be flushed out by means of a valve, V., leading direct to the filter.

The filtered effluent passes from the bottom of the filters into the effluent drain, E.D., a manhole being placed near the filters for the purpose of sampling the effluent from them.

The three examples just given will serve the purpose of showing the methods of treating varied conditions from varied points of view.

When it is thought desirable to use automatic alternating gear in or alongside the dosing chamber, this can be done very simply by arranging a copper float which rises and falls with the effluent in the dosing chamber, at the same time turning bevel gears, which can be devised so as to transmit the horizontal twisting motion of the horizontal axle to a corresponding motion in the vertical rod in the alternating gear chamber shown in Fig. 435. The bottom of this rod can then carry a circular disc (contrived with a ratchet and the gearing) to alternately open and close the entrance to pipes A and B, leading right and left, to the contact beds or the percolating filters shown in Figs. 427 and 428, or similar installations.

It should be pointed out that the architect of country houses and institutions requiring sewage-disposal plant, having decided the type of disposal scheme most suitable to the conditions, usually leaves the design of the details in the hands of a specialist firm, of whom a number are available in London and most large towns.

CHAPTER XIII

The Materials Used In Sanitary Work

Under this heading it is proposed to give short descriptions of the composition, properties, and manufacture of the principal materials used in the various branches of sanitary work.

Bricks. The principal use of bricks, from our present point of view, is for the construction of manholes and sewers, and for these items bricks should fulfil the following conditions:

1. They should be non-absorbent unless protected by a non-absorbent facing, such as cement rendering.
2. They should be well baked throughout.
3. They should be uniform in size, shape, and texture.
4. They should have sharp arrises or edges.
5. They should be free from flaws, stones and lumps of lime, the last named being liable to expand and split the brick.
6. They should ring well when two are struck together.
7. They should be strong and require repeated blows before breaking.
8. They should stand handling and cartage well without injury

Brick Earth. Bricks are blocks of clayey earth, baked or burned. Their quality depends on (1) the chemical composition of the earth used; (2) the amount of preparation it has undergone; and (3) the temperature at which burned, and the care with which the burning is carried on.

A good brick earth is generally composed of silica and alumina, together with a small quantity of lime or iron, or both, which act as a flux to fuse the particles together, giving silicate of alumina. Small percentages of other substances are also contained, such as magnesia, potash, soda and manganese, which give the colour to the brick. The colour is also dependent on the temperature at which burned; for example, the well-known Staffordshire blue brick owes its colour to a fairly large proportion of oxide of iron, which is, by a high temperature, converted from the red oxide to the black. A small proportion of iron, and a moderate temperature, give a brick of from an orange to a deep red colour, while bricks free from iron burn white. Magnesia gives a yellow colour.

Brickmaking. Brickmaking processes may be divided into four heads: (1) the preparation of the earth; (2) moulding; (3) drying; and (4) burning.

In the preparation of the earth the clay is first exposed by unsoiling or removing the earth above it, then dug, freed from stones, ground in some cases, and tempered, which consists practically of kneading.

Hand and Machine Moulding. The brick may be moulded by hand or by machine. Those used in sanitary work are usually machine made.

Machine moulding can be carried out in three ways:

1. By forcing the clay through an opening in the form of a plastic band, cutting off the bricks by means of descending wires, which of course give a brick without a frog. The marks of the wires can always be seen on a wire-cut brick.

2. By moulding the brick from powdered clay under great pressure, such bricks having usually a frog; and

3. By moulding the bricks in the ordinary way and then subjecting them to compression under a piston.

Pressed bricks of the last two classes have very true surfaces and hard edges.

Before the bricks are ready for burning they must be dried, which can be done either indoors or out.

Burning. The burning can be accomplished in two ways, either in a clamp or in a kiln. The clamp consists of a stack of raw bricks built up over a rough system of flues formed by bricks already burned, on a properly drained floor covered with burned bricks. The quality of the bricks is often very uneven.

Brick Kilns. Kilns are of two principal kinds, the intermittent and the continuous. The former is known as the Scotch kiln, and consists of a low, rectangular, roofless building, with a wide doorway at each end, and fire holes along each side. Flues are formed with bricks from side to side, the kiln is loaded, and the doorways bricked up. The whole charge of bricks is then burned, allowed to cool, and then the kiln is emptied. The best-known example of the continuous kiln is the Hoffmann, of which there are many forms, differing only in detail. They are chamber kilns, circular, oval or rectangular on plan, having chambers which are separated by removable doors. In some chambers the bricks are being placed, in some they are drying, some burning, some cooling, and some being unloaded. This system is now in use in all the large brickyards, and gives a regular supply independent of weather, the kiln being roofed.

Bricks for Sanitary Work. The best bricks for sanitary purposes are pressed red bricks, blue Staffordshire bricks, and hard bricks salt-glazed on the exposed faces, like the surface of a drain pipe. The salt glazing is obtained by the vaporisation of common salt in a special kiln, which covers all exposed faces with a thin film of glass.

Staffordshire Blues will stand a crushing strain as high as 16,600 lb. per square inch and are almost completely impervious to water. They are therefore eminently suitable for engineering or sanitary work where these qualities are necessary, particularly in underground work in wet or waterlogged soil. Moreover, in a position where the work would be exposed to sand-laden winds or alternate wet and frost they would prove very resistant to abrasion or erosion.

Pressed red engineering bricks (such as Accrington Reds) will stand up to a crushing test of 10,300 lb. per sq. inch, but are not quite so impervious to moisture.

Brown salt-glazed bricks and white vitreous-glazed bricks where a smooth easily cleansed surface is required such as in sanitary conveniences, or in the case of the latter, where their light reflecting qualities will be useful. When the brick carrying the glaze is absorptive and the bricks are used in a position where they are exposed to moisture from the rear (as in facing a retaining wall to keep back waterlogged soil) it may be found in frosty weather that the glaze will craze or flake off, pushed off by ice forming behind the glaze.

Useful data is available on the behaviour of clay engineering bricks in B.S. 1301, which specifies Class A engineering bricks to stand a minimum crushing test of 10,000 lb. per square inch and a maximum water absorption (after a 5-hour boiling test) of 4·5 per cent. of their dry weight, while Class B engineering bricks (for less stringent work) should show 7000 lb. per square inch and not exceed 7 per cent. water absorption respectively.

Stone. Stone is not largely used in sanitary work, but is useful in the form of slabs for the tops of manholes and similar situations, for which York stone is the best fitted.

Terra-cotta. This material is made by burning certain clays and is sometimes used for special invert blocks to egg-shaped sewers; it consists of well-burned clay generally a mixture of clays. It has a hard vitrified outer skin, which is usually indestructible by acids and which must not be interfered with, such as by chipping adjoining edges to make them even in surface, as this exposes the softer inside structure of the material.

Terra-cotta is almost always moulded hollow, with diaphragms or webs connecting the outer walls of the blocks, with a view to reducing the shrinkage, the hollows being then filled with fine concrete.

Cement. Cements are of two principal varieties, the natural and the artificial. The former are burned from natural lumps of a clayey or stony nature, and the latter are burned from a mixture of materials. Further, the cements can be divided into those suitable for internal and those for external work.

The principal cements for outside or underground work are Portland and Roman, and the principal for inside use are plaster of Paris, Keene's, Parian, and similar cements. The best and strongest cement is Portland, so called from its supposed resemblance in colour to Portland stone. It is made from a mixture of chalk and clayey materials. In some parts of the Medway, and on the Thames side, a mixture of chalk and river mud is used, the mixture being regulated so that the finished product shall have about 60 to 65 per cent. of lime, 20 per cent. silica, 10 per cent. alumina, and a small amount of other constituents.

Manufacture of Portland Cement. The measured proportions of chalk and clay are thoroughly combined by passing them through a set of three wash mills, forming what is termed slurry; it is then passed through very fine screens. The slurry is then elevated, by pumping, to storage and mixing tanks, in which it is kept in motion by mechanical stirrers. Here the mixture is sampled and chemically tested to see if it is of the desired composition and, if all is in order, it is conveyed or conducted to a special form of rotary kiln, to be dried and burned. The kiln is about 6 feet in diameter and 130 feet long. It is fixed with its length inclined to the horizontal. The slurry enters at the upper end, and is dried by the rising hot gases, probably in about the first sixth or seventh of the length of the kiln, and issues at the lower end in a stream of fine clinker. A temperature of about 2800° F. is kept up at the lower end of the kiln, the flames being fed by pulverised coal injected by an air or steam blast. The clinker falls into coolers, and is afterwards taken to the mill for grinding. This mill is of cylindrical form, lined with plates lapping one over the other like roof tiles, and contains a number of hard steel balls The rotation of the cylinder reduces the clinker to a fine powder, when it passes through perforations in the mill and is ready for further grinding. This is effected in another cylindrical mill containing specially hard pebbles, and known as a tube mill. This grinds the cement to such a degree of fineness as will allow over 90

per cent. of it to pass through a sieve having 28,900 holes to the square inch. To make the cement ready for immediate use, a special apparatus is attached to the end of the tube mill, which subjects the cement to a charge of super-heated steam at great pressure, this method superseding the old-fashioned method of spreading the cement over a wooden floor for a month or so to aerate it.

Portland cement for sanitary work should be of the very best quality.

British Standard Portland Cement. The best way to ensure that Portland cement is satisfactory is to state, in the specification, that the Portland cement shall comply in all respects with the requirements of the latest specification of the British Standards Institution (B.S. No. 12), adding the qualification "normal" or "quick-setting" as the case may require.

This standard specification has been revised from time to time; it is somewhat technical in character, so that it is unnecessary to include it in a volume of this nature.

Chief Qualities of B.S. Portland Cement. It will be sufficient, in this general treatise, to say that the specification prescribes tests for fineness, chemical composition, strength, setting time and soundness. It should, however, be mentioned here that the specification recognises two classes of cement, viz., "normal" setting and "quick" setting. The former will be cement which does not begin to set for thirty minutes after mixing with water, and in which setting is complete in something under ten hours; the latter will be cement which does not begin to set within five minutes of mixing and will complete setting in something less than thirty minutes. In any specification for sanitary or building work it should be stated which of these classes of cement is to be used; normal setting should always be specified unless there is some very special reason for requiring a quick-setting variety, as where it is difficult to keep subsoil water from the work for more than a very short period.

Rapid-hardening Cement. Of late years efforts have been made to produce cements which, whilst not beginning to set any more quickly, will harden more rapidly once setting has started. To understand the action it must be realised that the setting of cement depends on the combination of the lime with the alumina and with the silica in the presence of water, and that it combines with the alumina much more rapidly than it does with the silica. Acceleration of the hardening can be obtained by finer grinding of the cement, so that the particles of lime may be in more intimate

contact with those of the other materials; also by increasing the proportion of alumina very greatly, and, of course, diminishing the proportions of lime and of silica.

The rapid-hardening cements produced by fine grinding are known as "Ferrocretes" and it is claimed for them that in three days they will have the same strength that ordinary Portland cement has in twenty-eight days.

High-alumina Cements. The high-alumina cements are variously known as "Ciment Fondu", "Bauxite Cement", and "Aluminous Cement"; for them it is claimed that in one day they will have twice the strength that ordinary Portland cement has in twenty-eight days. The B.S. is 915.

The cost of Ferrocrete is about 15 per cent. greater than that of Portland cement and that of Ciment Fondu 100 per cent. greater. The use of the latter is on this account likely to be confined to cases where considerable economies can be effected by the early removal of timber shuttering, the quick filling in of trenches, and diminution of a period of pumping.

Blast-furnace Cement (B.S. 146). This is a comparatively new addition to the list of cements available. It utilises slag from blast furnaces in which limestone has played its part in the treatment of the iron. It may be obtained more cheaply than ordinary Portland cement—especially in blast-furnace areas. It is also more resistant to acid attack than Portland.

Use of Neat Cement versus Sand and Cement. Cement should not be used neat except as a cement wash or to make a joint required to be very smooth finish, such as the outlet of a W.C. pan to a soil-pipe or drain socket, as neat cement is more likely to expand or shrink on setting than a mortar made of 1 part of cement to 1 or 2 parts of sand.

By-laws sometimes compel the use of neat cement for drain or sewer jointing, with the idea that it will make the joint stronger and more watertight. Not only is it a needless extravagance, but, should the cement contract on setting, the cement will become loose in the sockets, in which case leakage must result. An admixture of at least an equal quantity of sand with the cement will prevent this and will at the same time reduce the cost of the work. The B.S. Code of Practice on Building Drainage favours the ratio of equal parts sand and cement.

Roman Cement. Roman cement is burned from calcareous nodules found in the London clay. It is used to a limited extent, its rapid-setting properties fitting it for work between tides or similar cases, but it has no great ultimate strength. It is said

that even before setting it resists water, and the tendency to being washed away, better than other cements.

Keene's, Parian and Similar Cements. Keene's, Parian and similar cements are suitable only for such purposes as wall linings for inside work, since they contain a large amount of gypsum, which is soluble in water. Both are manufactured from plaster of Paris, Keene's by the addition of alum, and the Parian by the addition of borax. They are very suitable for filling in cracks, because they expand in setting.

Sand. There are three sources from which this is obtained—from sand pits, river beds and the seashore. Pit sand is often angular, sharp and gritty, and on this account has generally been preferred, for making mortar or concrete, to river sand, the grains of which are usually rounded and smoother. Of late years careful experiments seem to have shown that angular grains are not superior to round grains; whether this is the case or not, the point is of small importance compared with that of obtaining a material which is free from any admixture of clay, loam, earthy or organic matter.

Sea Sand. Sea sand contains a large amount of salt, with the result that mortar and concrete containing it hold damp and effloresce. It should not, therefore, be used in mortar for brickwork above ground, or for any other purpose where dampness or efflorescence would be a disadvantage. For other purposes there appears to be no valid objection to its use.

Substitutes for Sand. When sand is not available crushed stone may be substituted, or even crushed furnace ashes, or blast-furnace slag. Such materials, however, should not be crushed too small, and with some stones—notably granite—it is difficult to avoid crushing it to fine dust, which results in a weak concrete. If any furnace residue is used there must be no trace of coal dust, as unburnt coal expands when wet and, if present in mortar or concrete, will cause it to crumble. Slag is a material which varies very much in quality and should not be used on important work without expert advice.

Mortar. For sanitary work, cement mortar is almost always used, composed of Portland cement and sand. It should be mixed dry, the ingredients being carefully turned over together two or three times before the water is added. The proportions range from one part of cement to one of sand, to one of cement and four sand. For jointing drain pipes, joints of brick sewers and similar work, one of cement and two of sand is a good proportion. Not more should be mixed than is immediately

required, as mortar which has commenced setting should not be re-mixed.

Concrete. As will have been seen, concrete, which is really an artificial stone, is largely used in sanitary work. There are two chief varieties of concrete, lime concrete and cement concrete; but the former is now but little used, cement concrete being desirable for any work required to be waterproof. Bituminous concrete is also sometimes used, this being a compound of bitumen with broken stone, the former taking the place of cement.

Cement concrete consists of three materials, Portland cement, sand and a larger aggregate, such as broken stone. The cement and sand, which has been sufficiently described above, together form a matrix or mortar which binds together the aggregate. The aggregate may be of broken stone, broken bricks, gravel, Thames ballast, coke breeze or furnace slag; the remarks made about the two last-mentioned materials, when dealing with sand, will, however, apply with equal force to their use as aggregates and they are not generally used in sanitary works. If unscreened gravel or Thames ballast is used no sand will be needed in addition to that which is contained in the ballast. This material is of uncertain quality. It used to contain about a reasonable amount of sand for the making of concrete, but now very often contains far too much. It all depends on the part of the river from which it is obtained and must therefore be regarded with caution.

Substitutes for Broken Stone. Whatever the nature of the aggregate chosen, it should be free from clay, loam and earth, or else freed from these by washing. If stone or brick is used, it should be broken to a size suitable to the character of the work to be executed, only pieces which are capable of passing through a screen of specified mesh being used, whilst small stuff, which passes through a much smaller screen, should be rejected.

Gauge of Aggregate. For heavy retaining walls or foundations the material should be capable of passing through a screen of 2 inches or $2\frac{1}{2}$ inches mesh; for work which is to be watertight, such as the walls of a sedimentation tank, a gauge of 1 inch would be reasonable, whilst for thin slabs of concrete and for reinforced concrete the maximum gauge should be about $\frac{3}{4}$ inch.

Proportions. The proportioning of the materials is of great importance, the ideal proportion for strength and watertightness being that in which the cement completely fills the voids between the grains of the sand, and the matrix so formed completely fills the voids between the pieces of the larger aggregate. This proportion can be determined roughly in the following manner. A

watertight box of known capacity is filled with the broken stone and water is poured in until the spaces between the stone are completely filled; the volume of water is carefully measured as it is poured in and this will be an indication of the amount of sand required. A similar test can be conducted on the sand, the amount of water added in this case being an indication of the amount of cement required.

It will generally be found that the proportions arrived at by these means will be about one part of cement, two parts of sand and four parts of stone, so that in reinforced concrete and other work which has to be watertight, these proportions can be used if great care is taken in the mixing. To allow for uneven mixing the proportions may be 1, $1\frac{3}{4}$ and $3\frac{1}{2}$ in important work. For the foundations of ordinary buildings, for support of sewers and other work in which watertightness is of no importance and only moderate strength is required, the proportions are commonly made 1, 3 and 6 respectively.

Watertight Work. Where a strong or watertight concrete is required the proportion of water added is of great importance and should be carefully controlled. It should be as little as is possible in order to produce a concrete which is easily workable. This proportion will vary with different aggregates and sands according to their initial wetness and their porosity. Only clean water should be used.

Concrete Mixing Machines. Concrete is preferably mixed in machines, in which there are fittings for measuring the various materials, including the water. In cases where a mixing machine cannot be used the ingredients should be carefully measured in gauging boxes and tipped on a boarded platform. They should then be turned over carefully at least twice, to mix them thoroughly, in the dry state. After this, clean water should be added through a rose, and the whole turned over again at least twice in its wetted condition. Concrete should not be tipped from a height, or the heavier particles will separate from the lighter. It should be gently lowered into position, deposited in layers not more than 1 foot thick, and each layer well rammed. If any layer has set before the next is added, it should be allowed to set hard and should then be roughened, brushed, wetted and coated with cement and water, a mixture known as "cement grout", before a fresh layer is put on.

Manufacture of Ware Pipes. The relative advantages of stoneware and fireclay for the manufacture of drain pipes have already been referred to. They are both manufactured, by machine, in

the same way. The machine is arranged so as to extend through two floors of the building.

On the upper floor is a steam cylinder, working a steel ram up and down. Below the ram is a hopper or funnel, formed in the floor and into which the clay is charged. Connected to the outlet of the hopper, and situate in the room below, is the steel pipe mould, having a core inside it, the socket being lowermost. There is a space between the core and the mould, which, if filled, and the mould and core then removed, would leave the partly finished pipe. At the lower end of the mould is a small platform which can be readily raised or lowered, and on this is the socket part of the core. The clay is charged into the hopper and the ram allowed rapidly to rise and fall, so as to make the mould compactly filled; clips, holding the platform to the base of the mould, are then released, and the ram allowed slowly to come downwards. This causes the pipe to descend out of the mould, following the movable platform downwards. When a sufficient length of pipe is through the mould, it is cut off by a thin steel wire to a length rather greater than its ultimate length. It is then taken to a revolving table, cut to its true length, trimmed up, and the grooves on the socket and spigot formed. The platform is brought up to its original position, re-clamped, and the operation goes on again and again. Bends are formed by the pipe moulder taking the lower end of the pipe, as it issues from the mould, and pulling it round to the desired curve. Junctions are formed of two pipes moulded as just described, a hole being cut in the side of the one, and the other cut to fit, the moulding being carefully completed by hand. More complicated pieces of stoneware are moulded in two halves and then put together, the joint being carefully made good.

Drying and Burning. The next step is to dry the articles, which is generally done in a drying shed, often over a kiln. They are then stacked in a dome-shaped kiln, having fire holes around its base, and burned for about three to four days, according to the composition of the clay. While in the kiln they are, when sufficiently burned, glazed by the vaporisation of common salt, applied either at the fire holes, or at the top of the kiln. The heat decomposes the salt into a gaseous vapour which coats every atom of exposed surface in the kiln, and forms an alloy with the surface of the clay. For this reason the salt glaze cannot be chipped off the pipe without taking off also a piece of the pipe itself. An alternative method of glazing, of greater expense, and with many disadvantages, is that known as lead glazing. This is applied, after the pipes or other articles have been burned and removed

from the kiln, by coating them with a mixture containing, among other things, oxides of lead and tin, silica, china clay, and borax. This forms, when burned in another kiln at a temperature of about 1000° F., a thin surface coating of a glassy nature, but one which does not combine with the material of the pipe, and can be readily chipped off.

Stoneware pipes, if required to be of "tested" quality, are tested by means of a hydraulic press, the objects of the test being to ascertain their powers of resistance to absorption, percolation and pressure.

As mentioned in Chapter IX the British Standards Institution have issued standard specifications for salt-glazed pipes and for tested salt-glazed pipes; to these standard specifications reference can be made in any specification for work (B.S. No. 65 for pipes and B.S. 539 for the corresponding fittings).

Cast Iron, Wrought Iron and Steel. The manufacture of these materials is too large a matter to be dealt with fully in a work of this kind, but the difference in composition and properties can be dealt with. The main difference in composition is in the proportion of carbon contained. Cast iron contains from about 2 to 6 per cent., wrought iron from 0 to 0·15 per cent., and steel from 0·12 to 1·5 per cent.

Cast iron is obtained by smelting the ore in blast furnaces and running the metal into moulds termed pigs. The pig iron should be remelted in order to obtain a good quality of iron. There are three kinds of cast iron, white, grey and mottled, which contains both the grey and white varieties. White and mottled cast iron are less liable to rusting than the grey variety, but the last mentioned is the material which, for its greater toughness, is used for structural castings.

Cast iron is crystalline in structure, gives but little resistance to tension, but great to compression. It is lacking in toughness and elasticity, being hard and brittle.

Wrought iron is obtained from cast by a series of processes, the object of which is to remove the carbon and the impurities which made the cast iron brittle. Wrought iron is of fibrous structure, very tough and ductile, easily forged and welded but not fusible, and gives high resistance to tension, though but little to compression.

Steel may be produced by adding carbon to wrought iron, or by removing a portion of the carbon from pig iron. There are a large number of processes by which this may be brought about. Mild steel is a material which is superior to wrought iron for all ordinary structural uses, principally in that it is stronger and more uniform

in texture. It has great tensile strength, and has greater resistance to compression than wrought iron, with a harder surface. It is also more elastic in nature. Mild steel is forgeable and weldable, like wrought iron. Given pieces of the same bulk, cast iron of good quality will last much longer than wrought, because of the rapid way in which commercial wrought iron goes to pieces by flaking, a process which does not apply to cast iron.

Iron Pipes. Cast-iron pipes are formed in a mould usually having a core in the middle. They can be cast horizontally, vertically or in an inclined position. All three methods are in use, but the vertical method is best, though perhaps less convenient to adopt. It gives pipes of more uniform thickness and greater density. The inclined method, in which the mould is placed at an angle of about 45° with the horizontal, also gives a good quality of pipe. The horizontal method is used chiefly for the lighter kinds of pipe, and does not give such a good pipe as either of the other methods. With the vertical method the pipe is cast with the socket downwards, to give maximum density at that part, and is cast of greater length than needed, by from 6 inches to a foot, so as to allow the dross and air bubbles to rise to the top, this part being afterwards cut off.

"Spun" Iron Pipes. Mention has been made in Chapter VII of an alternative method of manufacture in which the iron is "spun" by centrifugal force against a rotating mould, no core being used in this process.

B.S. No. 78 specifies vertically cast-iron pipes for pressure purposes and B.S. No. 437 similar pipes for drains. B.S. No. 1211 specifies spun iron pipes for pressure purposes. The fittings to be used in conjunction with cast-iron drain pipes are dealt with in B.S. 1130.

Wrought-iron Pipes. Wrought-iron pipes are made in three alternative ways. The strongest pipes, such as high-pressure hydraulic mains, are formed by winding a bar of iron spirally around a core, the abutting edges being then welded together. Pipes of this variety are of very great strength, and have been made to stand a stress of several tons per square inch without injury. The second method is that adopted for pipes of gas strength and consists of bending a bar round a core and then welding together the abutting edges, thus forming a longitudinal joint. Such a pipe should not be used for other than gas. The third method is similar, but the adjoining edges are lapped and welded instead of being merely butted together. This class of pipe is what is known as water strength.

Protection from Corrosion. As has been pointed out in earlier chapters, it is necessary to protect iron pipes from corrosion. The Angus Smith, galvanising and Bower-Barff processes have already been described. Another process is that of glass enamelling the inside of the pipe. This consists of coating them internally with lead glaze, as described for stoneware, and then firing them in a kiln. The great trouble with pipes of this kind is the difficulty of cutting them without removing part of the internal lining of glass and so exposing the iron to oxidation. Steel pipes are specified in B.S. No. 534.

Lead. This material is of great importance in sanitary work. Not only is it used for gutters, flashings, flat roofs, cisterns, damp courses, etc., but it is the material of which most of the pipes in a house are often formed.

Lead is produced by smelting ores, the ores from which it is principally obtained being galena and cerussite. It is a very malleable material and can be readily worked to almost any shape without applying heat.

Sheets of lead can be either cast or milled. Cast sheets are not often used, having several drawbacks. They can be obtained up to about 16 feet long by 6 feet wide, but are of uneven surface and thickness and liable to flaws and sand holes. Milled lead sheets are generally used both for flats and gutters, and also for all other sanitary work. They are obtained by first casting a large, thick block and then rolling and re-rolling it in a mill, having two very heavy steel rollers, until it has been reduced to the desired thickness. Part way through the operation, the sheet which is in process of formation is cut up into parts these parts being dealt with separately. Milled lead is obtainable in sheets up to about 35 feet long and 9 feet wide, though rather smaller sizes are more usual. As previously stated in another chapter, milled lead is described by its weight per superficial foot. The Standard Specification for sheet lead is B.S. No. 1178.

Ternary Alloys of Lead. One defect of lead is that under long continued strain, especially when subjected to vibration, it crystallises and becomes brittle. It has been found that this does not occur if the lead is alloyed with small quantities of certain other metals, and the resulting alloy is considerably stronger than ordinary lead. These alloys are known as "ternary alloys" and reference has been made to them in Chapter VII.

Red and White Lead. Lead is also used in sanitary work in quite a different form from the foregoing; that is to say, in the form of red and white lead, as used for jointing in certain cases. Red lead

is obtained by oxidising metallic lead in a furnace, by exposing it to the action of air. A coating of oxide is formed, and this is removed to expose a fresh metallic surface, this process being continually repeated. The oxide is then ground in water between stone rollers, and again exposed to the action of air in another furnace, which permits it to take up more oxygen and gives it its red colour. It is then re-ground in water and dried. White lead is made by exposing metallic lead to the action of the fumes of acetic acid in the presence of carbonic acid gas. The lead is suspended in jars over the acid and the jars usually stacked in tiers between permanent and temporary floors covered with tan. A stack formed in this way is left for about three months to ferment, when the heat vaporises the acid and causes the tan freely to give off carbonic acid gas. This forms a coating of carbonate on the lead, which is then removed and ground. To bring it to its ordinary commercial form, as used by the painter, it is then reground in linseed oil.

Lead in Contact with Portland Cement. It is now known that lead is affected chemically by damp Portland cement, and for this reason it is suggested that lead which comes into contact with cement should be previously coated with bitumen.

Lead Pipes. At one time lead pipes were made by bending the lead around a core and soldering the joint, and pipes of this kind are still sometimes found in old houses. Nowadays, however, solid drawn-lead pipes are used, and are seamless. They are made by forcing semi-molten lead through a die by means of a hydraulic press, or by the use of a ram actuated by steam. Over the head of the ram a thick cylinder of lead is enclosed in a very strong casing. At the top of the casing interchangeable dies can be fixed, varying of course with the size of the intended pipe. The ram works around a rigid pillar, to the top of which a short length of core is fixed, having a diameter equal to that of the pipe. Around this is fixed the die, which is larger in radius by an amount equal to the thickness of the pipe. Through the opening so left, the ram forces the lead in the form of a continuous tube.

Tin-lined Lead Pipes. In somewhat the same category as lead pipes are tinned-lead pipe and tin-lined pipe. The former is of drawn lead thinly coated with tin by the simple process of pouring a little molten tin into the lead pipe as it comes from the pipe machine, the pipe being sufficiently hot to keep the tin in a molten state. The tin amalgamates with the lead, to form a surface alloy to some extent, but the coating is far from uniform, and the resulting pipe little better than one of ordinary drawn lead. The tin-

lined pipe is an article of quite a different nature, there being a definite tube of tin inside the lead. The construction of the pipe is simple. In the casing of the pipe machine, instead of merely a thick cylinder of lead, is a cylinder in two parts, the inner one of tin and the outer one of lead, the ratio of their thicknesses corresponding with the ratio of the thickness of the tin and lead in the finished pipe. The pipe therefore issues from the machine as a tube of tin inside a tube of lead. The object of tinning or tin lining a pipe is to make it suitable for the conveyance of soft water without injuring its quality, but there is often considerable trouble with the joints, the lining being destroyed and laying the surface of the lead bare.

Standard Specifications for lead pipes (No. 602) and for ternary alloy pipes (No. 603) are available.

Bends and Traps in Lead. Bends and traps can be formed from drawn-lead piping by means of special bending appliances, but the solid drawn-lead bends and traps can be made in a pipe machine very similar to the one described already. The difference lies in the fact that, in place of the vertical ram, two horizontal rams are used. By setting them to work at varying speeds the lead is forced through the die at a faster rate on one side than on the other, thus giving a bend of radius depending on the relative velocities of the rams.

Lead Wool or Leadite. This substance consists of fine threads or shavings of lead, twisted to form a sort of rope. It is used instead of ordinary molten lead for caulked lead joints and is particularly suitable for work under water or in positions difficult of access.

Copper. This material is used for roofing and flashings, damp-proof courses, hot and cold water services (including back boilers, cylinders and tanks), soil and waste pipes, rainwater gutters and downpipes.

A reddish-brown metal, it is obtained by smelting ores, such as pyrites and malachite. It is tough, malleable and ductile and can be forged hot or cold. Cold working gradually hardens the metal, so that annealing is needed to restore a dead soft temper if the working is to continue past the hard stage.

For roofing purposes copper is obtainable in two forms, sheet and strip, the former being in basic sizes of 4 feet by 2 feet and 6 feet by 3 feet (though larger sizes are obtainable) and the latter in long rolls of any width up to 2 feet. When exposed to the atmosphere it takes on a protective coating or patina, which may vary in colour from a rich grey-green to brown, or even black, and may be either

a carbonate, sulphate or chloride of copper, according to the impurities of the atmosphere.

For damp-proof courses it is obtainable in long coils in all the usual wall widths and is specified in B.S. No. 743.

Copper tubing may be obtained in half-hard temper in straight lengths up to 18 feet and in soft temper in coils of length up to 60 feet. When water comes into contact with the interior of the tube a protective coating is formed, unless the water is very acid, in which case the water will get a green stain. The corrosion-resisting qualities of the metal, smoothness of bore, ease of jointing and neatness of appearance make a first-class plumbing installation, except for acid waters. The British Standard Specification for light-gauge copper tubes is No. 659.

Rainwater goods in copper are usually of 22 S.W.G. in half-hard temper.

Zinc. Zinc is used in connection with roof work, for lining cisterns in some cases, as a constituent of various alloys, and also for galvanising. Most of the zinc used in this country comes from Belgium, and its thickness, when in the form of sheets, is customarily measured by means of the Belgian zinc gauge. It is very brittle when cold, and also when raised to a temperature of about 400° F., but at about 220° F. it is very malleable and can be rolled into sheets, which retain their malleability. Zinc sheets are soon destroyed by the acid air of large towns and also by sea air. Another objection to zinc for roofing is that it blazes furiously at a red heat. Zinc sheets are obtainable up to a size of 8 feet by 3 feet.

Brass. Brass is an alloy composed of copper and zinc, the proportion varying according to the purpose for which the alloy is required. The best proportion for water fittings is 2 of copper to 1 of zinc.

Gunmetal. This material is suitable for high quality water fittings, and particularly so where the water is acid, such water injuriously affecting fittings of brass.

Gunmetal is an alloy of copper and tin, the best proportion for water fittings being 9 of copper to 1 of tin.

Solder. Ordinary plumbers' solder is known as soft solder, and is an alloy of tin and lead in the proportion of 1 of the former to 2 of the latter. For special purposes, bismuth is also added, as for jointing tin pipes. Hard solder, for use on copper, brass or gunmetal, is of different composition, consisting of copper, zinc and silver. For good ordinary work, it consists of from equal parts of copper and zinc to 2 of the former to 1 of the latter.

Fluxes. To assist solder to form a surface alloy with the metals with which it is in contact, and prevent the formation of an oxide on the surfaces of the materials which are being soldered, fluxes of various kinds are used. When using plumbers' solder for joining lead to lead, brass or copper, tallow is used, and when using fine solder (more fusible), resin and tallow. For use on brass, zinc or copper, chloride of zinc, also known as killed spirits, is used. Other fluxes are Gallipoli oil, for tin and pewter, and borax or sal ammoniac, for cast iron, malleable iron and steel.

Rust Cement. This cement, as stated when dealing with the jointing of iron pipes, is particularly suitable for iron pipes subjected to considerable changes of temperature. It is a mixture of fine cast-iron borings, water and sal ammoniac if required to be slow setting, or borings, water and flowers of sulphur if required to be more rapid in setting.

Limewash or Whitewash. Where it is desirable to give walls a cheap sanitary coating, lime whiting is often used. It is made from pure lime mixed with water, and the addition of 1 lb. of pure tallow to every bushel of lime improves its quality. It will not adhere well to smooth non-porous surfaces, but is an excellent preservative for both stonework and brickwork, protecting them from attack by the acids in the air. For external work, a good whitewash can be made by adding 4 lb. of sulphate of zinc and 2 lb. of common salt to every bushel of lime.

Distemper. Ordinary distemper is a mixture of whiting and size, the whiting being chalk reduced to powder, and the size a sort of thin glue made from the waste parts of animals, such as horns, hoofs and skins. The distemper can be coloured by the addition of various earthy pigments.

Many patent distempers, or water paints, are now obtainable, the makers in most cases claiming that their productions are free from size, which is always liable to decompose and smell. The smell from ordinary distemper can, however, always be obviated by the addition of carbolic acid. In place of size, water paints contain dried soapy soils, which serve the same purpose of giving adhesiveness to the paint. They are more washable than common distemper.

Where a more lasting surface than distemper is desired with either a matt or "eggshell" surface, a number of wall paints and emulsions are now available. The wall paints are packed ready for application by brush or spray, but the emulsions with a bituminous base need the addition of about 20 per cent. of water before brushing or spraying on. All the usual colours are available.

CHAPTER XIV

Sanitary Surveys and Reports

Vital Necessity for Good Drains. Amongst the general public there is usually too much of the feeling "out of sight, out of mind" in regard to sanitary matters. Householders make the great mistake of not looking on the drains as a part of the dwelling, and a delicate part at that. The drains stand in the same relation to the dwelling as the bowels to the human body. They carry off waste matters which it would be injurious to health to retain in the structure. A leakage of the bowels causes instant injury, whereas the injury due to a leakage of the drains is more gradually felt, but that is only because the proportions between the bowels and the body, and those between the drains and the house are different. In time, the ground adjacent or subjacent to the house becomes sewage sodden, giving off noxious emanations, to say nothing of its possibly injurious effect on any water supply there may be in the vicinity of the drain.

Chief Items in a Complete Sanitary Survey. The conditions which should be fulfilled by a really sanitary building have already been given under various headings, and there would be no useful purpose served by repeating them here. They will have shown, however, that in making a sanitary survey of a house, there are many points which require consideration; such as the general arrangement of the building, and in particular the relation between the position of the sanitary fittings and that of living rooms and bedrooms; ventilation, dampness, water supply, sanitary fittings, drainage, etc.

Let us consider in detail the procedure in making the inspection, the method of booking the notes, and that of writing the report on such information as is obtained.

A fundamental principle in sanitary survey work is that of taking nothing for granted. The surveyor may find a plan of the drainage at the house; he should accept it as information, but must satisfy himself as to its accuracy. He often finds a gardener or odd man about the house, who is most anxious to give him information in reference to such matters as the courses of the drains, but again such evidence should be verified. If in inspecting, say, the water supply he finds a casing over some of the pipes, such casing should be removed and the pipes traced from end to end.

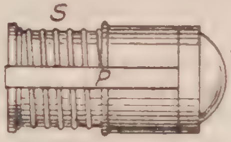
Testing the Drains. One of the most important things incidental to the survey will be the testing of the drainage system. There are four principal methods of testing, namely:

1. The Olfactory or Odour Test.
2. The Smoke Test.
3. The Water or Hydraulic Test; and
4. The Air or Pneumatic Test.

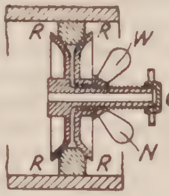
The Odour Test. The odour test is a very poor one, but one must not overlook the fact that occasionally the circumstances are such that the other tests cannot be applied. It may then be useful. The test is only suitable for soil and waste pipes and the joints around fittings, and can be applied in either of two ways. One is that of using a chemical drain tester. There are many varieties of these, consisting of packages of phosphorous compounds or other evil-smelling substances. They are put up in many forms, and consist of receptacles from which the smell-producing substance is ejected after passing through the trap. They are furnished with fairly long lengths of string, usually coiled round them, by means of which the receptacle can be withdrawn after use. An example of this kind of appliance is shown in Fig. 436 which illustrates what is known as a Kemp tester. It consists of a thin glass tube containing a chemical compound. The substance is kept in the tube by a cap and rubber washer, a spiral spring, S, around the tube tending to force the cap off. This is prevented, before use, by a strip of paper, P, which passes over the cap and down the two sides, to which it is fastened. The whole appliance is only about 2 inches long. To apply a test, it is flushed through the trap by a bucketful of water, hot if available; the hot water rapidly softens the paper strip and releases the contents. This example is illustrated merely to show the nature of such apparatus; there are many others made for the same purpose.

The other method of applying the olfactory test is by placing oil of peppermint in a bucketful of boiling water, about one and a half ounces of the oil to a quart of water. The liquid should be mixed and passed through the trap by an assistant, the surveyor himself keeping away during the process, as the smell is very pungent and readily clings to one's clothes. He then goes from room to room searching for traces of the smell which would come from leaky joints in the pipes or fittings or from an insufficiently sealed or unsealed trap.

The Smoke Test. The smoke test can be used for pipes below as well as those above ground, but it is not a satisfactory test for underground drains. In the case of defects above ground the

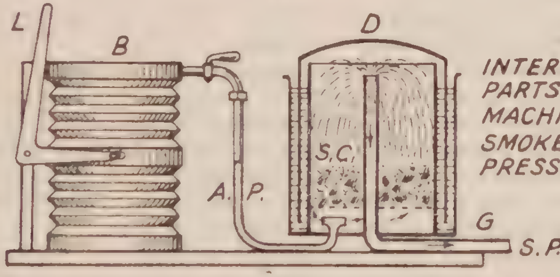


436
KEMP TESTER FOR ODOUR TEST

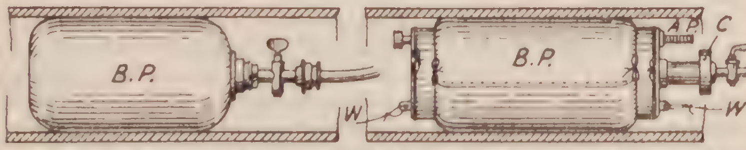


438
DISC PLUG FOR WATER, AIR OR SMOKE TESTS

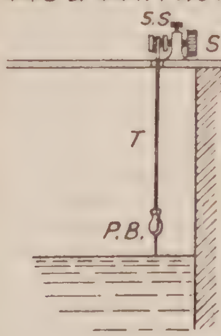
437
SMOKE ROCKET FOR SMOKE TEST



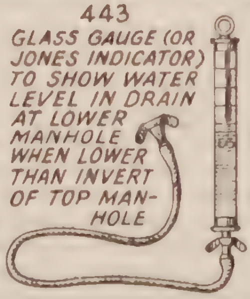
439
INTERIOR WORKING PARTS OF SMOKE MACHINE FOR SMOKE OR AIR PRESSURE TESTS



440 & 441. TWO FORMS OF BAG PLUG FOR WATER, AIR OR SMOKE TESTS



442
BEATTIE WATER TEST GAUGE TO MEASURE DEPTH OF WATER SURFACE BELOW TOP OF MANHOLE.



443
GLASS GAUGE (OR JONES INDICATOR) TO SHOW WATER LEVEL IN DRAIN AT LOWER MANHOLE WHEN LOWER THAN INVERT OF TOP MANHOLE

smoke is readily visible, apart from the smell, and in the case of a defective drain having only a shallow covering of porous soil the smoke will readily issue at ground level. With a considerable depth of earth over the pipes, or earth of a dense, damp nature, such as clay, however, the smoke will not find its way through. To facilitate its doing so, a probing iron is sometimes used, consisting of a pointed iron rod a few feet long, with a handle. It is used by walking over the course of the drain and forcing the rod down into the soil at frequent intervals so as to leave holes for the smoke to rise. The probing iron is also used for another purpose, that of probing the ground to locate the course of drains whose position is unknown or uncertain.

The smoke can be produced in two ways: (1) by a smoke rocket or smoke case, and (2) by a smoke machine.

The former is shown in Fig. 437, and consists of a cardboard tube about 8 inches long and $1\frac{1}{2}$ to 2 inches in diameter, the end being closed with paper. It has two wooden strips or fillets fixed to it, as shown at S, with a small nail through the middle. These should be turned round so that they are at right angles to the case, in order to keep the rocket off the invert of the drain, clear of the sewage. On lighting the paper and fuse at the end, a dense volume of smoke issues. The case should be removed from the drain after use.

The drawback to the use of smoke rockets is that the smoke cannot be produced under pressure, and to overcome this difficulty many forms of smoke machines have been introduced, differing largely in detail. The broad principle underlying them all is, however, the same; that of producing smoke under pressure by burning oily cotton waste, thick brown paper steeped in creosote oil, and other substances. Fig. 439 shows, diagrammatically, the essential parts of such a machine. S.C. is the smoke chamber, having a water jacket round it, a dome, D, fitting well down into the water space to provide a seal against the escape of smoke. Near the bottom of this chamber is a grating on which the smoke-producing substance is placed. The pipe for the conveyance of the smoke (S.P.) passes down the centre of the chamber, the inlet being near the top as shown. Alongside the smoke chamber is a double bellows, B, actuated by a lever, L. By this means air can be pumped through the air pipe, A.P., to the under side of the grating. The lever must not be worked too rapidly or it may cause the material to blaze instead of smoulder, with a consequently diminished amount of smoke. A pressure gauge is sometimes added at G in order to register the pressure applied.

Drain Plugs. In testing a soil or waste pipe, the drain should be plugged at the nearest manhole. This is sometimes only roughly done by means of wet cloths placed around the flexible pipe which is attached to the outlet of the machine, but it is far better to use a proper drain plug. There are two principal types of plug, (1) that consisting of a rubber ring capable of being expanded, and (2) that consisting of a rubber bladder which can be inflated by means of a small hand pump, and encased in coarse canvas to strengthen it and give it a great gripping power.

There are many varieties of each type, and it is not proposed to deal with them all; in fact it would serve no useful purpose to do so. Fig. 438 shows a section through one variety of rubber ring plug, consisting of two circular discs of iron which can be forced together by means of a wing nut, W.N., thus causing the expansion of the rubber ring, R.R. A screw cap, C, is provided at the outer end, which can be readily removed by means of the projecting lugs shown, either for the purpose of attaching a smoke pipe or for releasing the water when used for the water test. The original form of rubber ring was of circular section, but this did not give a good grip to the pipe, and later developments of this type have all tended towards giving greater gripping surface. The best examples of this type, however, do not give such an effective closure to the drain as a good type of bag plug.

The earlier forms of bag plug were of spherical shape, but these are not now so extensively used as those of cylindrical shape. Fig. 440 shows a simple form of bag plug in position. It is inflated by means of a hand pump similar to a bicycle pump, but of stronger make, and after inflation the small tap shown can be turned off. It will be obvious that such a plug will not only accommodate itself to any irregularities in the pipe better than a rubber ring, but will also give a much larger gripping surface and therefore a firmer hold.

A better form of bag plug is shown in Fig. 441. It has two brass ends, with means of attaching a string or wire, W, in order to permit of its being pulled either way, up or down the drain, before inflating it. A brass tube passes right through the bag, with a connection at C which can be used for attaching either the nozzle of the smoke machine, or a small tap to let the water out after a water test. The bag is inflated through a small pipe, A.P., and is closed after inflation by leaving on the tap of the pump.

Applying the Smoke Test. In applying the smoke test to a drain, the latter should be plugged at either end so as to form a closed chamber into which the smoke may be pumped. In the case of a

soil, ventilating, or waste pipe it is a good plan to test first with the top of the pipe open, and then, if possible, with it closed by means of wet cloths. The first test makes it possible to see if there is any blockage in the pipe, and the second puts a certain amount of pressure on the joints. The smoke test may be regarded as satisfactory for an uncovered drain, but it is not sufficiently severe for a covered one, whether new or old.

Care is necessary in the use of smoke rockets, as fumes of a suffocating nature are liable to accumulate at the bottom of the manhole.

The Water Test. We come next to the water or hydraulic test. It has often been argued that this test is an unfair one, as it puts a greater strain on the lowermost end of the drain than it does on the uppermost. This argument has some justification, but any drain may become blocked and is most likely to do so at the intercepting trap, in which case the water test will be at once applied naturally, the only difference being that the water in this case will be foul, with consequent danger in case of leakage.

It has been argued that the water test is not a fair one for other than new drains. The by-laws of local authorities all require new drains to be watertight, the inference being that unless they are so there is injury or danger to health. If it is necessary for a new drain to be watertight in the interests of health, it is equally so for a drain which is no longer new. The argument that the water test is not a fair one for old drains raises the proposition that while it is necessary for a drain, when new, to be watertight, there comes a time in the existence of that drain when that state of things is no longer necessary, but exactly how long after construction that time occurs is a point which I believe no one has yet had the courage to state.

One is well aware that perfect drains become imperfect, and that there are many substantial reasons why this is so, such as, in the case of our large towns, the vibration due to heavy traffic, but that does not alter the fact that a surveyor who allows a client, on the strength of his report, to enter into occupation of a house, the drains of which are not watertight, incurs a grave responsibility.

Broadly speaking, the water test is applied by plugging the lowest point on the drainage system and filling the drains with water until it stands at a depth of say not less than two feet in the upper manhole, a subsidence of the water indicating a leakage. The "head" of 2 feet mentioned should be looked upon as a minimum and the local by-laws may require a greater head. The B.S.

Code of Practice on Building Drainage (which is advisory only) advise a head of 5 feet at the upper end of the glazed ware drain under test, maintained for at least 10 minutes. If there is considerable fall on the drainage system it is wise to test it in sections, and wherever the system has several manholes it is advisable to test the length from one manhole to another, working downwards from the upper end, the object of this being to utilise the water from the upper lengths for the testing of the lower. In any case in which there are gullies at a lower level than the water in the manhole, they should be plugged in order to prevent the water issuing from them.

Relationship between "Head of Water" and "Water Pressure". "Head of pressure" is simply the height of a column of water, in lineal feet, above the point at which the internal strain or pressure is to be recorded. Provided the water is not flowing, the pressure in the supply pipe, at the point just behind the bathroom tap, is dependent on the number of feet, measured vertically, from the tap to the water surface in the service tank in the cistern room or loft. If this height is 10 feet, then the pressure at the tap, when shut, may be said to be 10 feet head. This may be translated to pressure per square inch by multiplying the "head" by 0·434, so "10 feet head" may be described as 4·34 lb. per square inch, and owing to the laws of hydraulics, this pressure operates upwards, downwards, left and right and indeed in every direction. The 5 feet head mentioned above thus indicates a pressure of 2·17 lb. per square inch.

Means of Measuring Subsidence. Great care is necessary in observing the water level and noting whether it subsides. If the sides of the manhole are of absorbent material, there is bound to be a drop in the water level owing to the absorption. In such a case the production of exact results is a matter of difficulty, considerable experience being needed in reference to the allowance for absorption. If the manhole sides are of non-absorbent material, the depth of the water surface below the top of the manhole can be accurately measured and noted. Anything like a chalk mark, or piece of stamp paper, as an indication of the original level of the water, is of little value, as it can be easily tampered with. The depth should be accurately measured down from the top and the figure booked. A neat contrivance for this purpose is that known as the Beattie water test gauge. It is shown in Fig. 442, and consists of a horizontal bar carrying an upright support for a small spindle, which passes through horizontally and has a milled-headed wheel, S, at one end, and a small drum, on

which is wound a tape measure, at the other. At the end of the tape, T, is a plumb bob, P.B., with a long point. It is allowed to fall slowly till the point touches the water surface and the spindle can then be clamped by a small set-screw. S.S. The apparatus can be lifted up from the side of the manhole and put in its case. no one but the observer knowing the water level.

Another way of safeguarding this question of water level is to use a "Jones Indicator" (or glass gauge). Fig. 443. which consists of a glass graduated tube, marked in inches and decimals. This can, by means of a flexible tube, be connected to the drain plug at the lower end, and once the water is at rest in the drain. its level can be recorded and noted, a lower reading later betraying any leakage. This appliance is also useful for readily determining the fall of the drain. If the latter is filled so that the water is just half-way up in the mouth of the pipe in the upper manhole, the total fall on that length of drain will be the depth from the water level in the gauge to the centre of the drain plug below it. Another use for the glass gauge is to ascertain the approximate position of a leakage if it exists. When there is no longer any lowering of water in the gauge, the height of water level above invert of manhole is read (say 15 inches) and horizontal distance back to the leakage can be calculated by proportion, if the gradient of drain is known. For a drain laid at $\frac{1}{40}$ with the indication assumed above of 1·25 feet the

$$\frac{\text{distance}}{1\cdot 25} = \frac{40}{1}$$

$$\text{From which distance} = 40 \times 1\cdot 25$$

$$= \underline{\underline{50 \text{ feet.}}}$$

A variant of the glass gauge is the "bucket gauge" in which a metal canister or "bucket" to hold about a quart of water replaces the glass tube.

This can be used for completing the filling of an unfinished length of drain at its upper end. while the glass gauge indicates water level and leakage at the lower end.

During testing, the plugs should be from time to time inspected to see that they are not allowing water to pass them. Another method of applying the water test is to attach a short length of $1\frac{1}{2}$-inch pipe to the plug by means of an elbow or bend. having inside it a small bore pipe to permit of the escape of air as the water enters the drain. The water can be allowed to rise in the pipe nearly to the top, and the depth of the surface below the top can

be measured and noted. If there are no manholes, the ground must be opened up at both ends, for the purpose of inserting a plug at the lower end, and of connecting a vertical bend at the upper, in which the water level can be noted.

It is by no means a common practice to test the length of drain from the interceptor to the sewer, but this can be readily done by floating a bag plug through the interceptor, attached to a wire or cord, and then inflating it. This length of drain should be as watertight as the remainder of the system. This possibility of floating the bag plug along the drain and then inflating it is a matter of very great value, for, by it, one is able to localise a leak in the system. Knowing that any length is leaking, float the plug down for a length of, say, 10 feet and then test that short length. If that is satisfactory, deflate the plug and float it on for, say, another 10 feet, and again test. This advantage is not, of course, attached to the use of rubber ring plugs, which can only be used near at hand.

It is a common practice to test soil and vent pipes by means of the water test, though it is considered too severe a test by many sanitary engineers. In passing new work it should certainly be done, but a smoke test under pressure is, by some authorities, regarded as sufficient for pipes which have been standing some years. The arguments in reference to the fairness of the water test for old drains also apply to this case.

The application of the water test is essentially a matter for a fine day, as in wet weather there is danger of rainwater finding its way into the drain. During the testing of any drain care should be taken that the sanitary fittings are not used, for the same reason.

The air or pneumatic test is one of which the merits have been much urged in recent years by the opponents of the water test. It applies a uniform pressure to all parts of the drainage system, but that, as already pointed out, does not indicate what happens if a drain becomes blocked at its lowest point, when the pressure to which the drain is subjected by nature is one which increases with the depth of any point below the free surface of the accumulated sewage.

The test is applied by closing all openings on the system and pumping in air by means of a small pump to which a pressure gauge is attached. If the traps on the system are not also plugged, no appreciable pressure can be applied, since a pressure of about 0·036 lb. per square inch on 1 inch of water will be liable to upset the equilibrium of the water seal. If the traps are plugged, any desired pressure can be applied.

Reasonable Pressure for Testing. It is generally accepted that stoneware pipe drains should safely stand a pressure of 3 lb. per square inch (about 7 feet head of water), while properly constructed iron drains should safely stand 10 lb. per square inch (about 23 feet head). The air having been pumped in to a pressure of, say, 3 lb. per square inch as indicated on the pressure gauge, the tap of the pump is closed. Any decrease in pressure recorded by the gauge will indicate leakage, but it will be seen that the method does not give good facilities for localising any leakage. The chief argument in favour of the air test is that air can get through defects which water cannot penetrate.

Drain Mirrors. Other appliances used in the testing of drainage are drain mirrors and electric lanterns. In inspecting a straight length between two manholes, a mirror may be placed in one of the manholes, and the small electric lantern in the other. The mirror is on a stand like an easel, and, if set up at a convenient angle, the observer can, by the aid of the light, note the internal condition of the drain by looking down into the mirror. The effect should be like looking through a tube. If the lantern is a powerful one, its light will be strong enough to illuminate the drain round a slight bend, in which case, although the reflection of the globe containing the light cannot be seen, there is sufficient illumination of the interior of the drain to permit of its interior condition being noted for an appreciable distance from either end.

Need for Periodic Testing. A drainage system requires maintenance in just the same way as any other part of the habitation, although this is a fact which is largely ignored. Any system of drainage should be regularly inspected and tested, say about every two years.

We now come to the procedure in making a complete sanitary survey. Arrangements should be made for the surveyor to be met on the site by a plumber, or preferably a plumber and a labourer, to act as assistants. In London some of the large firms of sanitary engineers keep men who are experienced in this particular work, and send them out with all the necessary apparatus to assist surveyors. The expense is inconsiderable, and the value of an assistant accustomed to the work is great.

Need for System in Sanitary Surveys. Having arrived at the site, the surveyor should first make a preliminary and cursory examination of the exterior of the house, and its surroundings. Having done so, he is in the position to instruct his assistant as to the removal of manhole covers, opening up the ground where

necessary, plugging the drains, applying the tests, and so on. While this is being done, he is free to turn his attention to the inside of the house until called out by his assistant in reference to points incidental to the tests.

Nothing is more important than that he should be systematic in his inspection. It matters not whether he starts at the top floor and works down to the basement, or vice versa.

The Survey Notebook. Let us assume that the inspection to be made is that of a fairly large house with a basement, and that he intends starting at the lowest floor and working upwards. His notes should be made in a systematic way in proper notebooks kept for this particular purpose. Special books are obtainable, with the various headings printed in, and with sheets of squared paper at intervals for the purpose of making sketch plans, but plain notebooks are better, as no printed notebook can give all the headings likely to be required for every possible case.

Having entered the descriptions of the property and the date, the surveyor should proceed to the basement and take notes of all matters coming under the heading of sanitation at this level before proceeding upwards; as to items which are satisfactory his notes need only be the briefest description, but unsatisfactory items should be noted in detail. As he deals with each room he should have regard to its lighting, ventilation and signs of dampness, if any, and locate the cause. He should look for gullies in the floor, making a careful search, and having any lumber removed in order that he may do so.

The Water Closets. If the room contains sanitary fittings they should be thoroughly inspected; if quite satisfactory the only note necessary is, say, "W.C. quite satisfactory", but before making such a note regard should be had to all the following points: floor, walls, type of apparatus, its condition and cleansing properties, trap, its form and condition, means of flushing, capacity of cistern, condition, ball-valve, overflow, flushing pipe, etc. together with all the joints around the apparatus and cistern.

Sinks. In the case of a sink, the surveyor should have regard to its material, condition, trap, waste pipe, point of discharge and its situation as regards light; also the nature and condition of the water fittings supplying it.

Having gone through the basement in this way, he should then go to the ground floor and follow a similar procedure; then on to the upper floors, each floor being completed before another is commenced. At the top of the building cisterns will usually be found; the surveyor should have regard to their situation, accessi-

bility, lighting, ventilation, material, capacity, condition, connections, overflows and all other details.

Hot-water Service. The hot-water service should not be overlooked and, unless satisfied that the service is efficient and sufficient, the matter should be settled by lighting the fire and noting the time taken to get hot water and the approximate temperature obtained.

Cold-water Supply. Enough has been written, no doubt, to indicate the general manner of proceeding, but special features will frequently occur. Thus, if there is any reason to doubt the quality of the water, samples should be subsequently taken in the manner previously described. If filters are found, they should comply with the requirements laid down herein for a satisfactory filter.

Testing the Gas Supply (if any). If gas is used in the house, some sanitary surveyors make a practice of testing the soundness of the gas piping. This is done by a small machine consisting of a pump, pressure-gauge and safety-valve. The pipes should stand a pressure of about 2 lb. per square inch, the method of applying the test being as follows: Shut off the gas at the meter, and connect the pump to a gas bracket by means of a flexible tube attached to the machine. Pump until the gauge registers the desired pressure; the finger of the gauge should then remain stationary. Should it not do so, the leakage can be traced by putting a small quantity of liquid ammonia in the machine and proceeding in the following way: Open the tap of a gas-fitting, preferably the farthest from the meter, to allow the air to escape, and then pump the fumes of the ammonia into the pipes. If a chemically prepared paper is then passed along the pipes, the ammonia fumes which are escaping at any leak will change its colour.

Exterior of House. On completing the inspection of the interior of the house, attention must be given to the exterior. Should there be an open area, one must have regard to the condition of its paving and to the facilities for draining it. If there be an ordinary timber floor to the room inside, note the provision as to air bricks for the ventilation of the space below it. In the case of non-basement houses one often finds air bricks blocked up by the banking up of flower beds, or formation of rockeries. The condition of the walls as regards evidence of dampness; of the roof as regards cracked or broken slates or tiles, defective gutters or flashings, and of the eaves' gutters as regards the necessity for cleaning out, all should be dealt with.

Waste and Soil Pipes. Next examine the waste pipes on the

faces of the walls, giving regard to the following points: materials, jointing, fixing and treatment of upper and lower ends, particularly as regards disconnection or [illegible] to which it is [illegible]. Note particularly whether the upper ends of soil and vent pipes are in too close proximity to windows or skylights.

Gullies, Grease Traps, Manholes, etc. [illegible] gullies, grease traps, etc., noting whether they are of satisfactory type, properly set, in clean condition, with sound covers and so on. Having done this the manholes need special attention, particularly as to their construction, arrangement, condition and covers. Incidental to this there will be the sufficiency or otherwise of the dimensions of the drains discharging into them.

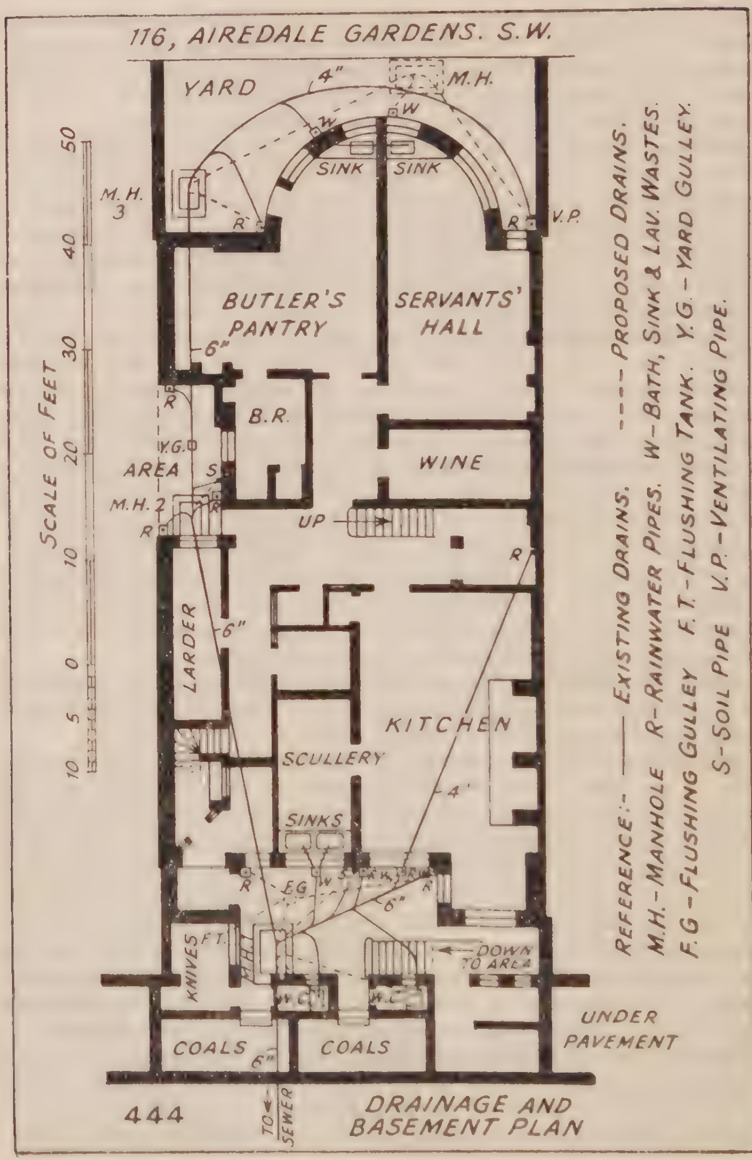
The Disconnecting Trap. The surveyor will have acquainted himself with the requirement of the local by-laws, and whether a disconnecting trap is required by them. [illegible] irrespective [illegible] the [illegible] of [illegible] of the building [illegible] [illegible] [illegible]. [illegible] by-laws are [illegible] [illegible] [illegible] [illegible], but it should be remembered that building by-laws set out to give the minimum that will satisfy the [illegible] authority concerned, and mere compliance does not of necessity [illegible] a healthy dwelling.

However that may be the surveyor should investigate the [illegible] or otherwise of intercepting trap between drain and public sewer, cesspool or private disposal plant and, if it exists, whether the interception is on a satisfactory basis, of a good type, and whether the stopper of its cleaning arm is secure.

Drain Ventilation. The method of ventilating the drains must be investigated, though the actual test of efficiency will be carried out in conjunction with the drain tests.

Inspection of Water Levels. While the surveyor is giving the bulk of his time to the foregoing items, he will be from time to time [illegible] by the necessity of [illegible] the water levels in [illegible], inspecting chambers and [illegible] of drain, but there [illegible] as he [illegible] [illegible] a [illegible] when the test is in operation. The methods of testing [illegible] [illegible] [illegible] [illegible]. If a [illegible] is found in the drains, its position should be [illegible] by [illegible] the bag plug through and [illegible] it at various points or by use of the glass gauge shown in Fig. [illegible] and described [illegible]. In the case of the paper [illegible] ground, the defective [illegible] or joint can be readily seen and its exact position located.

Sketch Plan of Drains and Block Plan of Buildings. A rough sketch plan of the outline of the building and the courses of the drains should be made, if none is available, so as to enable any proposed alterations to be shown on a plan attached to the report.


116, AIREDALE GARDENS. S.W.
YARD
4"
M.H.
W
SINK
SINK
M.H. 3
R
V.P.
BUTLER'S PANTRY
SERVANTS' HALL
6"
B.R.
WINE
Y.G.
AREA
S
M.H. 2
UP
LARDER
KITCHEN
SCULLERY
4'
SINKS
F.G
6"
F.T.
KNIVES
DOWN TO AREA
W.C.
COALS
COALS
UNDER PAVEMENT
444
TO SEWER
DRAINAGE AND BASEMENT PLAN
SCALE OF FEET
10 5 0 10 20 30 40 50
REFERENCE:- —— EXISTING DRAINS. ---- PROPOSED DRAINS.
M.H.-MANHOLE R-RAINWATER PIPES. W-BATH, SINK & LAV. WASTES.
F.G-FLUSHING GULLEY F.T.-FLUSHING TANK. Y.G.-YARD GULLEY.
S-SOIL PIPE V.P.-VENTILATING PIPE.

If any alterations are to be suggested, the approximate dimensions should be figured on this plan. In many cases the courses of the various drains will be fairly obvious from the inspection of the manholes and a comparison with the positions of the gullies and other features, but in any case of doubt the course of the drain should be traced by pouring coloured liquid through the gully or fitting. The water may be coloured by adding whiting, or cork dust of various colours is obtainable for the purpose.

The length of drain from the interceptor to the sewer should be tested, or, if there is no sewer, the cesspool should be carefully examined and notes made of any defects or objectionable features.

Sufficient has probably been given under this heading to indicate the general course of procedure as to the external inspection.

Example Sanitary Survey. The following example shows the notes which might be taken when making a sanitary survey of a good-sized house, using an ordinary notebook, and assuming, for convenience, that plans of the building and its drainage are available. The plan of the basement and its drainage is shown in Fig. 444, in conjunction with the report on the matter.

SANITARY SURVEY OF 116 AIREDALE GARDENS, S.W., FOR C. JONES, ESQ. 12TH SEPTEMBER, 1954.

INTERNALLY. *Basement.* Well lighted and ventilated. No internal gullies. Internal r.w. pipe at back of central staircase. Iron shoe at foot with screw-down cover in good order.

Servants' Hall. White-glazed sink, cracked; grating outlet. One and a quarter inch lead waste discharging into trap of B.P. Sink near by. Waste blocked. H. and C. supply. C.W. tap wants new washer.

Butler's Pantry. White-glazed sink, sound; plug outlet and overflow. Lead covered draining board. One and a half inch lead trap and waste through wall and over gully. H. and C. supply. Taps in good order.

Scullery. Two white-glazed sinks side by side, badly chipped and worn. One with plug outlet and overflow, other with grating. One and a half inch lead wastes, one discharging into trap of other. Waste through wall and over gully. H.W. taps want new washers.

Knife House. Draw-off tap in good order, no drip sink but cement floor with good fall to doorway.

Servants' W.C.'s. One adjoining area steps. Hopper pan and

trap, latter broken. Seat badly broken. Two gal. W.W.P. in good order but handle missing. Other, near by, pedestal wash-down, broken. Seat has balance weights, which have been cause of breaking pan. Two gal. W.W.P. in good order but handle missing.

Cement floors to both, good windows, and ventilated by space below door also.

GROUND FLOOR. *Cloakroom.* White glazed tip-up lav. basin. One and a quarter inch lead trap and waste through wall and over gully. H. and C. supply. Taps in good order.

W.C. adjoining. Wash-out apparatus, dirty condition. Dished marble safe, no waste pipe. Two gal. W.W.P. in good order. Well lighted and ventilated.

FIRST FLOOR. *W.C.* Exactly as last, otherwise in good order.

Bathroom. White porcelain bath. Fixed enclosure, pol. mahog. top. Lead safe under with W.P. through wall. Two-inch lead trap and waste through wall and over hopper head. H. and C. supply—taps in good order.

Draw-off tap beside bath, with lead-lined drip sink under waste through wall, all in good order.

White glazed lav. basin, weir overflow. One and a quarter inch lead trap and waste through wall and over hopper head. H. and C. supply—taps in good order.

SECOND FLOOR. *W.C.* Exactly as for first floor and ground floor.

Bathroom. Exactly as first floor, but no lav. basin.

THIRD FLOOR. *Slop Sink.* Brown's patent, properly trapped and discharging into soil-pipe. Two gal. W.W.P. over, also H. and C. supply. All in good order. Well lighted and ventilated.

Cistern. Large gal. iron cistern, with overflow through wall. Ball-valve in good order. Supplies all taps except the one in Knife House, which is off main.

HOT-WATER SERVICE. Large galvanised-iron cylinder beside range in kitchen. Service very efficient, but no safety-valve to boiler.

EXTERNALLY. *Area Pavings.* Cement, with good falls to gullies.

Dampness. Slight dampness on wall adjoining M.H. No. 2 in central area, due to split length of r.w. pipe.

Roof. Slate, about half-dozen cracked. Lead flashings sound. Parapet gutters require cleaning out.

Waste Pipes. R.W. pipes all in good order except one just referred to.

Hopper heads taking wastes from baths and lavs. rather fouled.

Soil-pipes. Centre area, near M.H. No. 2, 4-inch light lead with wiped joints. Badly bent and bruised. Takes W.C.'s on first and second floors. No anti-siphonage pipes. Carried well above roof. Grating perished. Joint at foot sound.

Front area, facing street, 4-inch light lead, square section, somewhat dented. From about 12 feet from paving it goes on up to near eaves in 4-inch iron, circular, and then on in 4-inch light lead, circular, to well above ridge.

Gullies. All ordinary stoneware yard gullies in fair condition. One grating broken in yard at back and one in front area.

Manholes. Three in all. No. 1 (front area) brown glazed stoneware channels. Bottom not benched and very defective. Walls cement rendered and in good order. Hinged iron cover, broken. Intercepting trap, stopper to arm missing.

No. 2 (central area) similar construction and benching defective as before. Cover badly rusted. No. 3 (at back) ditto, and cover broken.

Diameters of Drains. Main from M.H. 3 to M.H. 1 of 6-inch pipes, also 6-inch from angle of kitchen to M.H. 1. All others 4-inch. All under floors and pavings, ground not opened up, but appear to be stoneware socketed pipes and cement joints throughout, judging from manhole connections.

Ventilation of Drains. Outlet ventilation provided by S.P. in front and centre areas only. No V.P. at back. F.A.I. to M.H. 1 in a chase of wall of W.C. Mica flap valve, grating broken and flap missing.

Results of Tests. *Smoke Test on Soil-pipes.* One in centre area quite sound. Other, front area, weak at joint near eaves, between lead and iron.

Water Test on Drains. R.W. drain under kitchen discharging into back of gully, quite sound. Drains under yard slightly leaky. All other drains very leaky, particularly that from M.H. 2 to M.H. 1.

Chief Recommendations to be Considered While Still on Site. The surveyor should not leave the site until he has considered the recommendations he intends making. It is most important that he should bear this in mind so that he may make sure of the feasibility of such suggestions. There are often obstacles which are not obvious from a sketch plan, and it would not be to his credit to suggest amendments which cannot be carried out.

Advice to be Given. Having made the survey, the next step is the writing of the report. This is a matter calling for the exercise of considerable care and sound judgment. When making recommendations, all the circumstances of the case must be taken into consideration. It is, perhaps, easy to say, if the system of drainage is, generally speaking, unsatisfactory, remove the whole system and begin again, but if the client is a lessee with a fairly short unexpired term, this would probably lead to nothing being done at all, whereas moderate recommendations would probably be carried out. Counsels of perfection, if injudiciously given, tend to set back the clock of sanitary progress. The surveyor should take his client entirely into his confidence, and tell him frankly, if such is the case, that while a suggested alteration would be a great improvement, there would be no danger to health, under ordinary circumstances, in leaving that particular item as it is.

Avoidance of Technical Terms. When reporting to a lay client, care should be taken to keep the report as free as possible from technical expressions which a layman would not be likely to understand. To such a man, a report written in plain language must necessarily gain in intelligibility, and will certainly lose none of its professional value if properly done.

Chief Forms of Report. There are many ways of writing a report, each man having his own particular method, but the following are three good forms:

1. A formal report, headed as such, free from any personal element, a margin being left in which the various items are given as they are dealt with. The report on each item can be immediately followed by any recommendations which it is desired to make, or all the recommendations can be left until the end of the report. The former is usually the more convenient way, and the recommendations can then be briefly summarised at the end.

2. An informal report, written in a personal manner, in the form of a long letter. The marginal subheadings should be used in this case also, as they help a client readily to find any particular item. The recommendations can be dealt with in the same ways as given for form No. 1. The reports should of course be dated, and headed with the name of the property, after the opening words "Dear Sir".

3. A formal report, headed as such, arranged in, say, three columns, the first being headed Item, the second Report, and the third Recommendations, the report being signed and dated as before.

Example Report (Formal Type). It will be assumed that the surveyor prefers form No. 1. In that case his report, based on the notes already given, might read as follows:

REPORT ON THE SANITARY CONDITION OF 116 AIREDALE GARDENS, LONDON, S.W., FOR C. JONES, ESQ. 15TH SEPTEMBER, 1954.

GENERAL NOTE. The sanitation of this house, although of fairly recent date, is, generally speaking, in an unsound condition, and considerable remodelling and overhauling are necessary.

THE WATER SUPPLY. The water supply is derived from the mains of the Metropolitan Water Board, but there are no taps off the main except one in the Knife House. All the sanitary fittings are supplied from a large galvanised-iron cistern on the third floor. This cistern is in good order, and has an overflow pipe carried through the external wall.

It is very desirable that the taps over all sinks where water will be drawn for drinking or cooking purposes should be supplied direct from the main. The hot-water service is in an efficient state. There is a large storage cylinder in the kitchen, near the range, but there is no safety-valve on the boiler. It would be well to provide one and to overhaul and clean out the boiler and cylinder.

Hot and cold-water supplies are laid on to all the baths, lavatories and sinks. The water fittings are of good quality, but several taps require new washers.

THE SANITARY FITTINGS. *Water-closets.* There are internal closets on the ground, first and second floors. They are well lighted and ventilated, but each is equipped with a pedestal wash-out apparatus. This is a bad form of apparatus, the force of the flush from the cistern being expended in clearing out the basin, leaving no scouring effect for the trap. They should be replaced by a good type of wash-down apparatus. The closet is flushed by two-gallon water-waste preventing cistern in each case, and these are in good order. Each of the pans stands on a dished marble slab, intended to act as a safe, but these slabs should be provided with waste pipes passing through the external wall.

There are two servants' closets under the pavement, both being in a very insanitary state as regards the apparatus. In both, either the pan or the trap is broken, and in one the seat is badly broken. The flushing cisterns are quite efficient except that the handle of each is missing. Both these closets should be overhauled, and a good type of pedestal wash-down apparatus installed.

The paving, lighting and ventilation are satisfactory.

Sinks. There are five sinks. That in the *Servants' Hall* is white glazed, with a grating outlet, the waste pipe discharging into the trap of the *Butler's Pantry* sink nearby. This sink is cracked and should be renewed. At the same time a trap should be provided and a new waste pipe taken direct through the wall to discharge over a gully.

The present method of dealing with the waste is unsatisfactory and the waste pipe is now blocked.

The *Butler's Pantry* sink is white glazed, but with plug outlet and overflow. It is in good order and is fitted with a lead-covered draining board. The sink is trapped and the waste pipe discharges through the wall over a gully.

The *Scullery* has two sinks, side by side, both white glazed, one with grating outlet and the other with plug and overflow. Both are badly chipped and worn and should be replaced by new. The waste pipe from one passes into the trap of the other. When putting in the new sinks this should be altered, and each sink separately trapped and provided with its own waste pipe, passing through the wall and discharging over a gully.

A *Slop Sink* is provided on the third floor, properly trapped and discharging into a soil-pipe. This fitting is of good quality and in sound order. The small apartment in which it is placed is well lighted and ventilated.

The tap in the *Knife House* has no drip sink under it, but the floor is of cement and has a good fall towards the doorway. There is, therefore, no harm in not providing one.

Baths. There are two baths, on the first and second floors respectively. Both are of good white porcelain, have fixed enclosures and polished mahogany tops. Fixed enclosures are not desirable, but otherwise the baths are all in good order. Each has a lead safe under, with proper waste pipes. The baths are trapped and provided with good-sized waste pipes discharging through the walls, over hopper heads.

In each bathroom there is a draw-off tap beside the bath, with lead-lined drip sinks and proper waste pipes.

Lavatory Basins. There are two of these. That in the cloak-room, on ground floor, is an old-fashioned tip-up basin of white glazed ware, with properly trapped waste pipe carried through the wall and discharging over a gully. This fitting is not very sanitary, and should be replaced by a good modern type of basin, such as is provided in the first-floor bathroom.

The lavatory there is in excellent order. Its waste pipe is trapped and discharges over a hopper head.

THE DRAINS. The courses of the existing drains are shown on the accompanying plan by firm lines, their diameters being figured. They were not uncovered during the inspection, being all under floors and pavings, but from the connections with the manholes they appear to be of ordinary stoneware socketed pipes, jointed in cement. The water test was applied to the whole of the drains. The rainwater drain under the kitchen is quite sound, but all the other drains are defective. The length under the yard at the back is slightly leaking and is very badly planned. The other drains all leaked badly, but particularly the length between manholes Nos. 1 and 2.

It is strongly urged that the whole of the drains, except the length under the kitchen, be taken up, the trenches properly disinfected, and the drainage relaid with heavy cast-iron pipes, protected against corrosion by the Angus Smith process, and with caulked lead joints, the pipes being laid on concrete. The plan shows the suggested modifications by means of dotted lines. These modifications occur under the yard at the back, and under the front area, the courses of the remaining drains being kept as at present. The complicated junctions under the front area should be done away with, the two W.C.'s and the soil taken separately into the manhole, and the various other wastes collected into a large gully between the scullery window and manhole No. 1. It should be flushed by means of a 30-gallon automatic flushing tank, fixed in the Knife House, and discharging at least once a day.

Manholes. There are three manholes for inspection. They are all of defective construction at the bottom, which is formed of glazed stoneware channels set in concrete, the remainder of the floor being practically flat and badly broken up, instead of being well benched up in cement. These should be remodelled on up-to-date lines, with white glazed channels and proper benching. The walls are rendered in cement and are in fairly good condition. The iron covers to Nos. 1 and 3 are broken, and that to No. 2 is very badly rusted. All three manholes should have new heavy galvanised-iron airtight covers. An intercepting trap is provided to manhole No. 1. It is of satisfactory type, but the stopper to the cleaning arm is missing and there is nothing to shut off the air of the sewer to which the drains are connected. It is important that a proper airtight stopper be provided forthwith. It is suggested that another manhole be added in the yard at the back, which will greatly improve the arrangement of the drainage at this point.

Gullies. The gullies are all ordinary stoneware yard gullies. In remodelling the system, channel gullies should be put under the outlets of waste pipes from baths, lavatories, and sinks, the ordinary form being retained for the rainwater pipes. If the system is carried out in iron, the new gullies should be of iron. Two of the present gullies have broken gratings.

Ventilation of the Drains. Outlet ventilation is provided by means of the soil-pipes in the front and centre areas respectively. There is no outlet ventilating pipe at the head of the system and one should be provided as shown on the plan attached hereto. The inlet for fresh air is placed in a chase in the wall of the W.C. adjoining manhole No. 1 and is fitted with a mica flap valve which is badly broken. If the new vent pipe is added at the back, this fresh-air inlet can be removed entirely, sufficient inlet being provided in such case by the soil-pipe in the front area.

Rainwater Pipes. The rainwater pipes are all in good order, except for a split length on the wall adjoining manhole No. 2, which has caused slight dampness on the exterior of the wall. This length should be removed and a new one provided.

Waste Pipes. The wastes from the baths and lavatories above the ground-floor level are discharged into hopper heads of rainwater pipes. These heads are all rather fouled and the practice of using them for this purpose is not to be commended. To make a good job, main waste pipes of lead should be provided, carried well above the roof and finished with open ends for the purpose of ventilating them. Where two fittings discharge into the same waste pipe, the traps should be properly ventilated to protect them against siphonage.

Soil-pipes. The soil-pipe near manhole No. 2 is of light lead, 4 inches in diameter, with wiped soldered joints, but is badly bent and bruised. The joint at the foot is sound, and the pipe is carried well above the roof, but its otherwise defective condition makes it desirable to remove it and provide a new heavy lead pipe of 3½ inches in diameter, together with 2-inch lead anti-siphonage pipes to the traps of the W.C.'s discharging into it. The soil-pipe in the front area is partly of lead and partly of iron, partly square and partly circular in section. It is somewhat dented and the tests disclosed the fact that it was a leaky joint. The square section is particularly insanitary. This pipe should also be replaced by a proper one as just described, and both should have domical wire gratings at the top to prevent obstruction by birds.

Roof and Gutters. There are about half a dozen cracked slates, which should be removed and replaced by new ones.

The lead flashings are in good order, but the parapet gutters are badly in need of cleaning out.

SUMMARY OF RECOMMENDATIONS. The foregoing recommendations may be briefly summarised, as follows:

Additional draw-off taps to be provided from the main water supply pipe.

Hot-water service to be overhauled and safety valve added to boiler.

New washers to be provided to taps where needed.

Present closet apparatus to be removed throughout and new pedestal wash-down closets provided.

Waste pipes to be put to the marble safes.

Handles to be provided to cisterns where missing.

New sinks to be put in Servants' Hall and Scullery, and waste pipes remodelled in both cases.

Lavatory basin in Cloakroom to be replaced by one of modern type.

The drainage to be remodelled, involving relaying nearly the whole in iron pipes, including remodelling manholes and building one new one, overhauling and renewing gullies, etc.

New soil-pipes to be provided in place of existing ones, with anti-siphonage pipes.

New outlet vent pipe to be provided at the upper end of the system, and old fresh-air inlet removed.

Rainwater pipes to be overhauled, and new waste pipes provided, ventilating any traps where necessary.

Roofs and gutters to be overhauled.

(Signed) A. SURVEYOR, F.R.I.C.S.

20 *Blank Street,*
London, S.W.

The plan to be attached to the foregoing report is shown in Fig. 444. It will be seen from the foregoing that technicalities can be largely avoided in writing a report. Another point to be avoided is that of writing a report too much like a specification of the suggested work. The specification is a separate matter entirely, and, being intended for a builder or sanitary engineer, can be in technical language. It would also give much more detailed information as to sizes and materials.

A formal report such as the foregoing would be accompanied by a letter acknowledging receipt of instructions, and stating that the survey has now been made, etc.

Beginning of Report in Informal Style. If the foregoing report had been written in accordance with the second method given, it might be somewhat as follows:

20 *Blank Street, London, S.W.*,
15*th September*, 1954.

DEAR SIR,

116 AIREDALE GARDENS, LONDON, S.W.

In accordance with the instructions contained in your letter of the 10th inst., I inspected this property on the 12th inst., and now have pleasure in reporting to you thereon as follows:

GENERALLY. The sanitation of the house, although of fairly recent date, is, generally speaking, in an unsound condition, and considerable remodelling and overhauling is necessary.

THE WATER SUPPLY. The water supply is derived from the mains of the Metropolitan Water Board, but there are no taps off the main except one in the Knife House. All the sanitary fittings are supplied from a large galvanised-iron cistern on the third floor. This cistern is in good order, etc., etc., etc.

I am, Dear Sir,
Yours very truly,
A. SURVEYOR, F.R.I.C.S.

To C. Jones, Esq.

Beginning of Report in Tabulated Style. If, on the other hand, the third method be adopted for the report, a covering letter would be needed, and the report might read as follows:

REPORT ON THE SANITARY CONDITION OF 116 AIREDALE GARDENS, LONDON, S.W., FOR C. JONES, ESQ. 15TH SEPTEMBER, 1954.

Item	Report	Recommendations
Water Supply.	From mains of Metropolitan Water Board. Large galvanised-iron cistern on third floor, in good order. It supplies all sanitary fittings. No draw-off taps on main supply pipe except one in the Knife House.	The taps over all sinks at which water will be drawn for drinking and cooking purposes should be supplied direct from the main.
Hot-water service.	etc. etc.	etc. etc.

(*Signed*) A SURVEYOR, F.R.I.C.S.

20 *Blank Street*,
London, S.W.

The importance of drawing up the report after the fullest consideration of all the circumstances, economic and otherwise, must always be borne in mind, the conditions under which sanitary surveys are made being so very diverse. As already pointed out, one is often justified in making very moderate recommendations, which will lead to the improvements being made, whereas counsels of perfection might lead to nothing being done at all.

CHAPTER XV

The Collection and Disposal of Refuse, The Cleansing of Streets, Disinfection and Smoke Abatement

The disposal of refuse is a most difficult but important part of the work of local authorities. The nature and quantity of the refuse varies with the locality to some extent, particularly that part of it which comes from trade and industry.

Average Composition of House Refuse. An average of composition of house refuse, expressed as percentages of weight, would be about as follows:

Fine dust 28 per cent., cinders 26 per cent., paper 15 per cent., putrescible matter 14 per cent., cans and other metal 4 per cent., glass and crockery 3 per cent., rags 2 per cent., bone 1 per cent., unclassified matter 7 per cent.

Average Calorific Value of House Refuse. The calorific or heating value is usually between one-fourth and one-seventh that of good steam coal.

It should be borne in mind, however, that the composition and calorific value vary considerably according to the season, mainly because coal fires are more general in winter than in summer. It is interesting also to note that, owing to the greater use of gas stoves, electric cookers, and such appliances, the refuse is altering in character, containing much less cinders and ashes than hitherto, causing the calorific or fuel value to be lower. A natural corollary of this is that the cost of destruction is increasing far more steeply than increase in wages would justify. In some places refuse destructors, which used to be worked entirely by refuse, have now to be assisted by means of small coal, coke breeze or cheap oil.

When it is pointed out that the average amount of refuse collected per annum is about a quarter of a ton per head of population, it will be seen that the dealing with the waste matters of a large population is a big undertaking.

The most sanitary method of dealing with it is to cremate it. This is done, in a well-administered locality, in special furnaces, known as refuse destructors. Much could be done to reduce the difficulty and cost of destroying it if householders realised that they

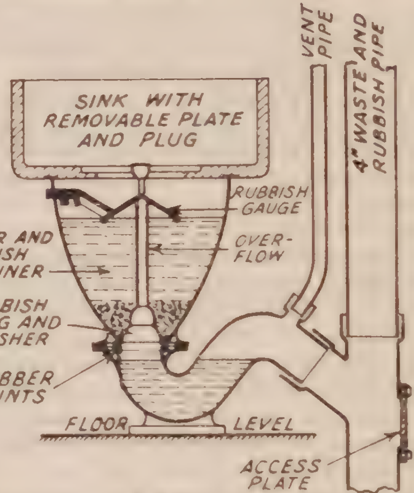
had some personal liability in the matter, and burned as much refuse as possible in their stoves or grates, preferably depositing waste vegetable matter in compost heaps in their gardens.

Storage of Refuse by Householder. Fixed ashpits are fortunately a thing of the past and for dwelling-houses portable galvanised iron bins, of a capacity not exceeding 2 cubic feet, should be insisted on. The gauge of the iron is often No. 20 B.W.G. and they are sometimes, but not usually, corrugated to give increased strength. A seating hoop should be provided at the base, to keep the floor of the bin off the ground, and the top edge should be strengthened by a stout galvanised iron hoop, to help preserve the shape; two strong galvanised iron handles are riveted to the body. It should be covered by a lid with a deep rim, which should fit loosely over the body, as bins often get rough usage by the dustmen and some distortion in shape may occur. The bin should be kept on an impervious floor, such as in a paved yard. It should be strongly impressed on householders that they should not put liquids or very wet refuse in bins and that they should not burn refuse in them.

Collection of Refuse. The usual practice in large towns is for refuse to be collected from dwelling-houses once in each week, with a more frequent call (perhaps daily) at hotels, restaurants and large blocks of flats. A weekly collection is by no means an ideal arrangement, for it is not desirable that putrescible matter should be kept so long in the immediate neighbourhood of dwellings and some towns have instituted a bi-weekly, or even daily, call with conspicuous success and at no great increase in cost.

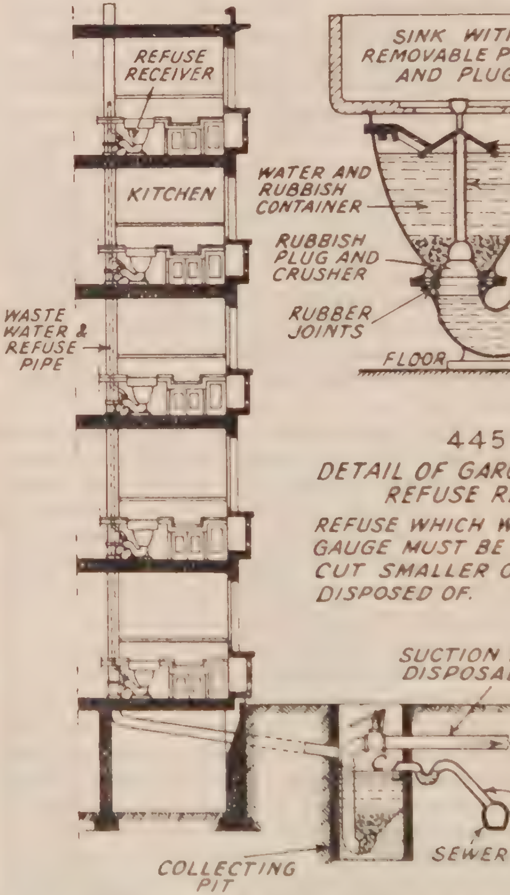
If bins are provided for flats and tenements they should be much smaller than those used for dwelling-houses and they should be emptied each day to a large "property container", placed outside the building at ground level, serving the block. This daily removal from the flat is necessary because the bins will usually be kept indoors; for the same reason they should be made pleasing in appearance, enamelled inside and out, with a hinged lid which in some types is made to open by pressing a lever with the foot.

Dust Chutes for Flatted Dwellings. An alternative method of removing refuse from flats is by its discharge to the ground floor through chutes 12 or 14 inches in diameter, with a well-fitting door at each flat. The doors should not be placed inside the flats if it can be avoided, as some nuisance from smell and dust is unavoidable. The chute should extend upwards above the roof, like a chimney, for ventilation purposes, and there should be facilities for washing it down with water periodically.



445
DETAIL OF GARCHEY SINK AND REFUSE RECEIVER.

REFUSE WHICH WILL NOT PASS THE GAUGE MUST BE REMOVED AND CUT SMALLER OR OTHERWISE DISPOSED OF.



CONTROL 'C' IN COLLECTION PIT MUST BE CLOSED WHEN BULK OF RUBBISH HAS BEEN REMOVED BY SUCTION PIPE AND BEFORE THE MAIN BODY OF WATER IS DRAWN INTO THE OUTLET PIPE.

446. THE GARCHEY METHOD OF REFUSE REMOVAL FOR LARGE BLOCKS OF FLATS.

The property container for a block of flats will be a solidly-built steel box, capable of holding 2 or $2\frac{1}{2}$ cubic yards of refuse, fitted with dust-proof sliding lids, with four small wheels running on rails on an iron stand, from which it can be removed to the collecting vehicles and taken away, a cleansed container being substituted on the stand.

The Garchey System of Refuse Storage. This is a system of water carriage for refuse in large blocks of flats and tenements to replace ordinary dust chutes which are apt to cause nuisance from dust and smell especially in hot summer weather. It was first used in Paris, but has been used with success at Leeds and elsewhere in this country.

The method (which is illustrated in Fig. 446) involves the provision of a special type of kitchen sink with a 6-inch diameter outlet in its bottom, normally closed by a metal cap in the centre of which is the ordinary waste outlet. The sink is used for ordinary purposes with the cap fixed in place, whilst solid refuse can be disposed of through the large outlet when the cap is removed. Under the sink is a cast-iron pear-shaped receiver whose outlet is closed by a plunger, fitted with an overflow, and into this both liquid wastes and solid refuse pass. Below the receiver is a trap, with 2-inch water seal and anti-siphonage pipe, connecting it to a vertical cast-iron gravitation pipe, extending from below ground to a level above the roof, being open at the top like a soil-pipe for ventilation purposes. The contents of the receiver are from time to time discharged to this by pulling up the plunger which normally closes the outlet of the receiver.

The gravitation pipe leads to an air-tight collecting chamber, placed underground outside the building. This has a trapped overflow, leading to the main drain or sewer, for continuous discharge of liquids, but the solids at the bottom are removed intermittently. This is done through a suction pipe which leads to the receiving tank of a disposal station, discharge being controlled by a hand-operated valve. The suction is effected by a motor-driven vacuum pump placed at the disposal station and it is claimed that discharge can be obtained for a distance of 5 miles by this means although, for obvious reasons, the receiving and destructor station is usually provided by the landlord of the complete block or series of blocks of flats and in the grounds or curtilage of the flats. When the solids and liquids reach the receiving tank they are lifted together by compressed air to a feed tank from which they gravitate to a hydro-extractor, where water is removed by centrifugal action; the residual refuse falls into an incinerator,

the heat from which can be used for a laundry or similar purposes.

It should be added that it is made impossible for the tenant to pass into the receiver from the sink articles so large that they might cause an obstruction. Large articles, if they cannot be broken up, must be disposed of in some other way.

The advantages of the Garchey method, as compared with the discharge to a container by chutes, are that dust and smell are avoided. The capital outlay is greater than that of dust chutes but the running costs are not very much greater.

Vehicles Used for Dust Collection. At the beginning of this century, the vehicles used for dust collection were horse-drawn wooden carts with open tops and high sides and the dustmen had to mount a short ladder with the bin, before tipping, in a cloud of dust, into the cart. To-day, they are usually motor-driven and controlled. It is important that the vans should be enclosed and that it should be possible to discharge the contents of bins without the dust being blown about.

There are many good designs of van, covered by close-fitting steel shutters; in some of these the shutters at the sides are raised and lowered by pedals, operated by the dustmen before and after emptying the contents of a bin. They have small wheels and a long low body to avoid the use of ladders. A more recent development is the moving floor type of vehicle. This type has a floor which resembles a rolling shutter shopblind in appearance, carrying a barrier about 3 feet high extending across the whole width of the vehicle. Loading is effected at the rear end of the van, behind the barrier; when the refuse reaches the level of the top of the barrier the floor and barrier are moved forward a little and loading is continued, the floor being moved forward at intervals until the barrier reaches the driver's end.

Most modern collecting vehicles have devices by which the body can be tipped to a steep angle for discharging its contents quickly and completely at the place of disposal, the tipping mechanism being actuated by gearing from the engine which normally propels the vehicle.

Another excellent modern vehicle has inside it a helical screw which gathers the refuse, as it is shot into the body, passes it forward and compresses it. Tipping gear is not needed, as the load is emptied by reversal of rotation of the screw. An advantage of this type is that a much greater weight can be carried in equal space, due to the compression.

Refuse Containers for Hotels, Flats, etc., in Populous Areas.

Property containers from hotels and blocks of flats can be carried conveniently by a motor lorry, of which the body can be tilted to form a sloping platform. The containers run on their own wheels and are drawn up the platform by a cable worked from the engine, after which the platform is brought to the horizontal.

Method of Locomotion. It is not possible to generalise as to the best method of propelling collecting vehicles. Whilst to-day the petrol engine is most commonly used, it is not at its best when used in a service which requires frequent stopping and waiting; on the other hand it is most efficient when long distances have to be travelled to the place of disposal. Where the houses are rather scattered and there is no great length of haul to the tip, horse-drawn vehicles may still be the best proposition and there are to-day horse-drawn vehicles of quite satisfactory design; but where development is more dense, or longer hauls to tip are necessary, the petrol-driven vehicle would be preferred. Some districts find it an economy to use a fleet of tractors with a larger number of trailers which can be moved quickly to strategic points for filling and then transported (two or three at a time) to the place of disposal.

Electrically-driven vehicles are occasionally used and they have some distinct advantages, for there is little or no loss at stopping and starting and no power is used when the van is stationary. The main objections to them are that the accumulators, which are used to drive them, are a considerable dead weight, that maintenance of accumulators is a serious item and that the speed of such vehicles in the travel to the tip is invariably low.

In some cases special means have been devised for taking advantage of the merits of the horse in a collecting vehicle and of the petrol engine in the travel to tip. One such method is to collect the refuse into small horse-drawn containers, holding about 3 tons, and to haul these, when full, up an inclinable ramp on to a motor lorry for haulage to tip, the horse being transferred to an empty container delivered by the lorry. Another method is to collect the refuse in trailers, which can be horse-drawn in the collection and coupled to a tractor in the haul.

Methods of Disposal. While the best method of disposal is by burning, many other methods are in use. In the case of some towns near the sea, refuse is barged out to sea in special barges and dropped into deep water. This method has its drawbacks; in winter the weather is often such that the barges dare not go out for sometimes a week at a time, which necessitates storage and consequent nuisance. Again, the tide will often bring a quantity of the lighter particles of refuse back.

"Controlled Tipping". In many districts refuse is tipped on low-lying lands, sand wastes, moorlands, disused quarries, etc. There has in recent times been much criticism of this practice, on the grounds that such tips are unsightly, form breeding-places for rats and flies, and cause unpleasant smells, sometimes increased by combustion of the refuse. To prevent these results the following precautions must be taken:

Before tipping is begun the surface soil of the site should be removed and set aside for covering the refuse; the refuse should be spread evenly to a depth not exceeding 6 feet and neatly banked; tins should be raked to the foot of the bank, placed upright and filled with earth; carpets, linos, rags, etc., laid flat at the foot of the bank and covered; glass and china should be broken up and paper consolidated by ramming; cinders and ashes should be brought to the top; each day's tippings should be covered with a layer of earth at least 9 inches thick.

Whilst "controlled" tipping of this character is not as satisfactory, from the health point of view, as burning, it will generally be much less costly. The refuse will be quite harmless in two or three years and the site will be suitable for agricultural purposes or for use as a public open space.

Salvage. When refuse is to be burnt it is sometimes found that it is profitable first to salvage from it such articles as cinders, rags, tins and bottles; the practice, too, has the advantage of diminishing the amount which has to be incinerated. The salvaging is done partly by screening, partly by hand-picking, and partly by the use of electro-magnets to pick out iron.

Cinders may be saleable for brick-making, rags for paper-making; tin and solder can be recovered from cans by chemical or electrolytic methods, and the remaining iron in the cans will be saleable if compressed into bales. The prices obtained in pre-war years for these by-products, however, seldom repaid the cost of their separation.

During the late war special efforts were made to salvage metals, paper, rags and other useful materials; householders were asked, in the national interest, to keep these clean and separate from other refuse and (in many districts) to take them to depots or dumps, from which the salvaged materials were collected by the local authority.

Refuse can sometimes be sold, or given away, to farmers as manure, and it much improves heavy clay soils. Disposal in this way will, however, be impossible unless the larger articles have been removed by salvaging, or pulverised.

Pulverising. Pulverising is done by heavy hammers, swinging in a revolving drum, the material falling as dust through a screen. Tins, and other articles which cannot be broken, must first be removed. The object of pulverisation is to make the refuse more suitable as manure.

Refuse Destructors. In the early days of destructors objection was made that they were nuisances to a neighbourhood, producing offensive smells, and that fine ash or dust was carried up the chimney shaft and scattered for a considerable distance around. Before the scientific principles underlying their construction were understood, there is little doubt that such complaints were well founded, but such great advances have been made that sanitarians are now agreed that the plan of disposing of towns' refuse by burning is the only really satisfactory one.

Essentials of a Satisfactory Refuse Destructor. The essentials of a satisfactory destructor installation are that its position should be fairly central, to economise cost of cartage; it should convert the organic matters into harmless and useful inorganic matters; and there should be no nuisance from smell, smoke, dust or other cause.

In early types of destructor the furnace was at a comparatively low temperature and fed by a natural draught of air. Modern destructors have forced draught, causing a high furnace temperature, with consequently more thorough combustion of gases and less liability to the causing of a nuisance.

Early Types of Refuse Destructor. The design of refuse-destroying furnaces has been built up on a foundation laid by the first destructors installed in England and erected at Manchester in 1876, the inventor's name being Fryer. A brief description of the original Fryer destructor will serve the purpose of showing the lines on which development has taken place.

It consists of a group of cells, each of which constitutes a separate furnace, consisting of a wide but shallow arch with inclined fire bars below it. The disposition of the cells is largely a matter of convenience, depending on the exigencies of the site, but they are often placed in two rows, back to back, as shown in Fig. 447. Each cell is about 9 feet front to back, and about 5 feet wide. The front of the furnace is formed by the fire bars with the arch over them, the former being of very heavy section and set to an inclination of about 1 in 3. The back of the furnace is divided into two parts, one in the form of an opening through which the gases, given off by the burning refuse, pass to the main flue, as shown in the left-hand half of Fig. 447, and the other in the form

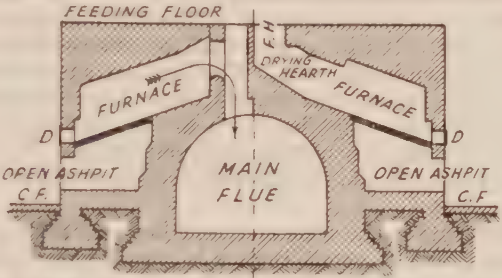
of a charging opening or feed hole, F.H., with an inclined drying hearth below, as shown in the right half. In other words, Fig. 447 shows a section through two cells, placed back to back, the section at the left being through one part of the cell and that at the right through another part. The top of the destructor forms a platform on to which the vans bring the refuse by means of an inclined road. The opening for the entry of refuse is divided from the opening for the exit of gases by a wall, and the refuse is prevented from getting into the main flue by the round-topped low wall shown in the section. In this original form the main flue was made very large, so as to act as a dust catcher, and the ashpit below the fire bars was open at the front, adjacent to the clinkering floor, C.F. The clinker was removed through doors formed at D.

The cells are provided with special openings for the introduction of infectious bedding, diseased meat, dead animals, etc., which fall direct upon the burning refuse and are consumed without nuisance.

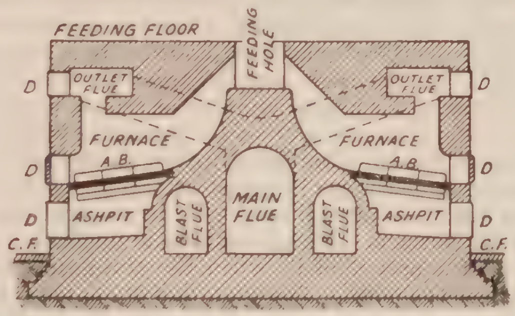
The Horsfall Destructor. It will be seen from the section in Fig. 447, that the gases given off by the burning refuse pass straight into the main flue and do not get that cremation which is so desirable. The first great advance was made by the Horsfall destructor, in which the gases pass over the hottest part of the fire to an outlet flue in front, leading down to the main flue as shown in dotted lines in Fig. 448. The ashpit was enclosed and a forced draught provided for. This was done by providing a blast flue for each row of cells, placed alongside the main flue to get a fairly high temperature. The air is driven through the blast flue by means of a powerful steam jet at the end and enters the ashpit through air boxes, A.B., at the sides of the cell. The sides of the cells are particularly liable to damage and the clinker is very liable to adhere to them. The air boxes are arranged with plates which are readily renewable. It will be seen that there is no drying hearth in this form. The fire bars are shown by a thick black line, as in the previous example. There are three doors to each cell, the top one for cleaning the outlet flue, the next for clinkering, and the lowest for access to the ashpit.

One advantage of placing the cells back to back is that the main flue can be placed between them and its high temperature thereby be preserved. The fire grates generally vary from about 25 to 42 square feet in area.

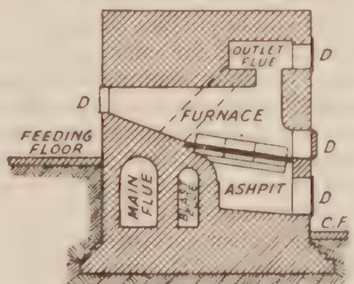
The addition of the forced draught, and the alteration of the position of the outlet flue, led to the cells being able to consume about twice as much refuse per day as was possible before, and at a lower cost.



447. EARLY TYPE OF DESTRUCTOR WITHOUT FORCED DRAUGHT AND OPEN ASHPIT. (BACK TO BACK CELLS)



448. HORSFALL DESTRUCTOR WITH FORCED HOT DRAUGHT, CLOSED ASHPIT AND TOP FEED. (BACK TO BACK CELLS)



449. FORCED HOT DRAUGHT DESTRUCTOR WITH BACK FEED FROM LOW CHARGING FLOOR. (SINGLE ROW OF CELLS)

Some destructors are fed at the top, some at the back, and some from the front. An example of a back-fed destructor cell is shown in Fig. 449. It will be seen that this is a modification of the Horsfall type shown in Fig. 448. The furnace is fed from a feeding floor, below the top of the destructor. This method is quite sound, as there is no great loss of heat by opening the charging door, owing to the front situation of the outlet flue. Front feeding, on the other hand, is open to the objection that there is more loss of heat.

As already stated, the refuse should have as little handling as possible, and in large installations systems of mechanical feeding are now widely adopted. The refuse is first tipped into a large hopper, from which it travels on a belt conveyor to small hoppers, placed over each furnace.

Tub Feeding Destructors. As an alternative the Horsfall Tub Feeding system may be installed. A large container or tub is lowered, by an overhead travelling crane, into a charging pit, so that the carts can tip their contents directly into it at ground level. Each tub holds about two tons of refuse, and enough tubs are provided to receive the storage for the hours when collection is not going on. The tubs are lifted to the high level by the crane and placed on a platform to await charging. When a furnace has to be charged, a tub is lifted by the crane and lowered into a cradle over the furnace. The descent of the cradle opens the charging door and the ascent of it, when the tub is lifted again after charging, closes the door. The operation of charging the two tons into the furnace takes less than a minute, the system effecting a great saving of labour and increasing the working capacity of the cell. Further, it ensures the maintenance of a high temperature.

Heat Utilisation. It is usual to utilise the heat from the furnaces to generate steam, which is used for various purposes such as the generation of electricity, pumping water or sewage, and so on.

Further improvements have been made in destructor practice. Thus, the air is heated to a high temperature before admission to the blast flue, the heated air raising the temperature of the furnace by an amount equal to nearly twice as much as its own temperature. The air heater is arranged in the form of tubes, through which the waste gases pass after serving the boilers, thus raising to a high figure the temperature of the air around the tubes. Such air is then driven to the ashpit by means of either steam blowers or fans. Both fans and blowers have their advocates, but a blower would seem to be better where a pressure has to be overcome.

Not only does the hot air raise the temperature of the furnace, it also helps to absorb the moisture in the burning refuse.

Temperature Created. The temperature of the waste gases of a good destructor is far higher than that of the gases from an ordinary boiler furnace. Under the old natural-draught system a temperature of about 900° F. was seldom exceeded, but in the case of a good modern high-temperature furnace the figure ranges from about 1500° to 2000°. The gases, after serving a boiler and being utilised for heating the air for the forced draught, can be further used to warm the water which is on its way to the boiler. This is done in what is termed an economiser, an apparatus somewhat like a hot-water coil, the waste gases playing round the pipes.

Dust Chambers or Interceptors. An important feature in a destructor is the combustion chamber, generally arranged at the end of a row of cells, the object being to bring down the velocity of the gases, on their way to the chimney shaft, to a low figure, so as to ensure the deposit of dust in a position at which it is easily accessible. Alternatively the gases are passed through a whirling chamber, where they are made to rotate rapidly, so that the dust is separated by centrifugal force.

While the cellular plan is the original, some types of destructor are not split up into separate cells, but have a continuous fire grate from end to end, with undulating arches over them to deflect the gases over the fire on their way to the flue. Here, again, both methods have their advocates and good examples can be pointed to on either system.

Woodall-Duckham Destructor. A type of destructor with novel features is the rotary furnace type of the Woodall-Duckham Co. The refuse is dried on a moving inclined and stepped hearth, after which follows the ignition stage, in which it is partially burnt upon an inclined grate, of which alternate fire bars are mechanically rocked to move the refuse forward. Combustion is aided by a blast of air from below. The refuse falls from the end of this grate into the upper end of an inclined rotating kiln, lined with firebrick. As it cascades down the inclined kiln the refuse is completely consumed. The gases from the ignition grate and from the kiln pass into a large combustion flue, from which they pass to the boilers. The dust is extracted from the gases after these leave the boiler flues and before they pass to the chimney.

It is claimed for this plant that labour cost is reduced, that less ground space is required to deal with an equal quantity of refuse, and that there is complete absence of dust and fumes from the chimney.

Ventilation of Destructor Building. The building in which the destructor installation is housed requires careful ventilation. If possible air inlets should be provided to introduce fresh air, while the used and tainted air is withdrawn by the combustion flues. One of the best ways is to provide an air duct high up in the building, communicating with the air supply for the forced draught. The forced draught, by this arrangement, pulls the air out of the building and passes it to the underside of the furnace grate.

Capacity of Cells. The quantity of refuse consumed per cell in twenty-four hours varies according to the make of furnace, method of stoking, nature of draught, etc., and can be anything from 8 to 20 tons. The percentage of clinker left, after burning the refuse, averages from 25 to 33 per cent.

Residuals. The composition of the clinker also varies greatly, but it was stated by H.P. Boulnois to be, generally:

Silica	69·4 per cent.
Iron and alumina oxides . . .	21·4 ,,
Carbonate of lime	9·2 ,,

the composition of the fine ash being much the same, but containing more silica.

Many destructor installations have, in the past, been failures by reason of the fact that efforts were being made to get too much out of them. The complete destruction of the refuse must always come first and foremost in any satisfactory installation, and the raising of steam, etc., be an after consideration. There are, however, certain residuals incidental to any such process. As has been seen, the waste gases can be utilised for raising steam; bottles and tin cans can be rescued and, lastly, there is the clinker. When finely crushed (if of good quality) it can be used instead of sand in mortar and plaster, for sanding slippery roads, and for bedding paving slabs. It is also used for fine concrete, such as paving slabs or paving laid *in situ*. The slabs are generally of three parts fine clinker and one part Portland cement, moulded under a pressure of about 60 tons per square foot. In some places bricks have been made from the clinker. Thus pressed bricks have been made of one part of Portland cement to nine parts of finely crushed clinker. The resulting brick is only very slightly absorbent and is strong; it is grey in colour and is used for fixing bricks, since it will take nails.

Other uses for clinker are for filter beds for sewage, filling up low-lying land, and under the foundations of concrete roads and

paved footpaths. but often destructor clinker is of too poor a quality to be useful for any purpose.

Street Cleansing. The cleansing of streets is a matter which, generally speaking, is quite distinct from the destruction of house refuse, though part of the street refuse is often mixed with that from the houses and taken to the destructor. Street refuse consists of dust, mud, rubbish, road-scraping, ice, snow and filth.

Streets must be kept clean primarily for sanitary reasons, but also for appearance, comfort and convenience. Dust carries organic impurities, and is a means of spreading the germs of disease. That from wood pavements is especially injurious to the lungs and eyes. From the point of view of cleanliness, the materials used for road surfaces may be placed in the following order: (1) Asphalt. (2) Concrete. (3) Wood paving. (4) Tar macadam. (5) Granite setts, and (6) Macadam.

In this classification it is assumed that all are in good condition; it should be borne in mind, however, that an old and worn wood surface, for instance, would be more difficult and costly to cleanse than a new surface of tar macadam.

Comparison of Different Types of Road Surface. A little consideration will disclose why some types of surfacing are more costly to cleanse than others. Thus, asphalt is non-absorbent and jointless, therefore such garbage as collects on it can be readily removed. Granite setts, however, though practically non-absorbent, have a multiplicity of joints in which garbage can collect. Water-bound macadam is easily worn down and produces dust and mud. On the other hand it should not be overlooked that very smooth materials, such as compressed rock asphalt, have to be gritted in wet weather and that this increases the amount of material which has to be scavenged.

Method in Organisation. The secret of success in cleansing streets is method. A definite system should be mapped out and strictly adhered to. Not only should the local authority cleanse the main and side streets, they should be made liable also for cleansing courts and alleys. In a well-regulated town, the main streets are swept or cleansed at regular intervals, once a day for preference, gathering the dust or debris into heaps along the gutters, or into slots at kerb level, leading to small bins under the kerb or footpath. From there, the dust may be transferred to a hand barrow.

Suburban streets do not need such frequent cleansing as the busy streets of the town, and it is usually sufficient to cleanse them about twice a week.

Asphalt and wood-block roads should be frequently washed, but in many cases one hears of the difficulty of obtaining the necessary supply of water. In most places there is only one supply for all purposes, public and private, and it is a matter for consideration whether an unfiltered supply for washing streets, fire extinction, and such purposes, could not advantageously be provided.

In rainy weather the street orderly boys should be armed with squeegees, with which to push the slop which forms on the surface into the side channels. This tends to keep the road surface clean and safe for traffic.

Macadam and granite sett roads are best cleansed by sweeping, either by hand or machine.

Hand Sweeping. Hand sweeping is still largely done, and possesses the advantage that it can be done only to those places which need it, whereas a machine will sweep all the road, whether it needs it or not, and is liable to leave mud and dirt in pot-holes.

Motor sweepers, however, are extensively used in large towns. There are many good types, of which a few of the commonest will be described.

Machine Sweeping. One such machine is a four-wheeled motor vehicle, with a rotary broom fixed between the two axles at an oblique angle. The broom is turned in direction opposite to that of the wheels of the vehicle, being driven by a chain from the gear box. The road is swept in two halves, the mud and dust being brushed into the channels. Other vehicles follow for its removal, after the channels have been swept by hand. Other designs of sweeper have water tanks and sprays, in order to wet the surface in front of the brushes and so facilitate the removal of dried mud.

Another type of vehicle is provided not only with water tank, spray and brush, but also a collecting bin into which the sweepings are brushed by three further rotating brushes. Another machine similarly sweeps the refuse into a bin mounted on a trailer.

Disposal of Street Sweepings. The disposal of street sweepings is generally a troublesome matter. The scrapings from macadamised roads can generally, if washed, be used with lime or cement for mortar. Mud is often tipped on waste land, but it should not be placed on possible building sites. It can also be mixed with house refuse and burned in a destructor.

Street Watering. Apart from the question of cleansing is the question of watering streets in order to keep down the dust in dry, windy weather. In the case of wood-paved roads the watering is also beneficial to the wood itself, making it less subject to

injury by abrasion. In crowded districts, or in times of epidemics, disinfectants should be added to the water. An example would be 1 lb. of permanganate of potash and half a pint of sulphuric acid to 100 gallons of water. Blocks of a disinfectant termed pynezone are also used for this purpose.

The road may be watered by a hose or by means of a water cart. In England the latter method is the more usual, both horse and motor-driven carts being used. The water either issues through a perforated pipe or is distributed by falling on two rotating discs or spreaders. A good cart or wagon will spread the water over a width of 20 feet, the quantity used varying from one-tenth to one-fifth of a gallon per square yard of surface.

Snow Cleansing. In the case of snow, it is difficult to do anything until the fall has ceased, when all available men should be set to work, dealing with the streets in the order of their importance. The snow should be banked up at the sides of the road, clear of the channels and gullies, with gangways through where desirable. Snow ploughs, both horse and motor driven, are also used. The disposing of the snow often gives trouble. Sometimes it is tipped down manholes into the sewer, but this is only possible with very large sewers. The best plan is to cart it away to the parks and open spaces and tip it on the land. If the town is on the banks of a river, the snow can be thrown into the river.

An application of salt greatly facilitates clearance, since it lowers the freezing temperature of water and therefore causes the snow to melt. The resulting slush, however, must be promptly swept away.

The expense of completely clearing streets of snow is very great. For example, it has been said that to clear a 6-inch fall of snow from the streets of London would require more vehicles than exist in that area. Any idea of doing more than to clear the principal streets of any large town, after a heavy fall of snow, is one for the squandering of a large sum of money.

Disinfection. A few brief notes on the subject of disinfection will not be out of place in the present volume.

The principal infectious diseases are: cholera, chickenpox, diphtheria, erysipelas, influenza, measles, mumps, scarlet fever, smallpox, enteric fever, typhus fever, tuberculosis, and whooping cough. Most diseases are caused by bacteria or micro-organisms, hence the urgent necessity for disinfectants and antiseptics.

Distinction Between Disinfectants, Antiseptics, Deodorants and Disinfestants. A *disinfectant* is an agent which will kill the germs of disease, such as hot air, steam, formaldehyde, sulphur dioxide,

chlorine, chloride of lime, perchloride of mercury, carbolic acid and many proprietary preparations mainly derived from coal-tar.

An antiseptic is an agent which will prevent the multiplying of bacteria, such as refrigeration, desiccation, alcohol and, in many cases, a weaker dilution of a disinfectant.

A deodorant is an agent which will absorb disagreeable odours —sometimes the term is applied also to agents which will mask or hide such odours, though that would not be a true deodorant. Dry earth of suitable type forms a good deodorant, so, too, do proprietary preparations containing a good concentration of chlorophyl, while oxygen and ozone are also excellent in this respect.

A disinfestant is an agent which will destroy disease-carrying pests like rats, mice, fleas, lice, bugs, mosquitoes, flies, etc. Hydrocyanic gas, mentioned later, is one of the best, but is deadly poison and should be used by an expert and with extreme care.

Value of Fresh Air and Sunlight. Fresh air and sunlight have considerable germicidal properties, but quick and complete destruction of germs, or true disinfection, can only be brought about by either chemical means or heat. In most districts there is a public disinfecting station, where articles can be sent for disinfection. Such a station will be described later.

Disinfection of Clothing. Where articles of clothing and bedding cannot be sent to a disinfecting station they should be burned if possible; otherwise they should be boiled or soaked for twenty-four hours in some disinfecting liquid, such as a solution of Izal, 5 parts to 100 parts of water; chloride of lime, 2 ounces to a gallon of water; carbolic acid, 5 parts to 100 parts of water; or perchloride of mercury, ½ ounce, hydrochloric acid, 1 ounce, and aniline blue, 5 grains, to 3 gallons of water. Perchloride of mercury, or corrosive sublimate as it is often called, is a cheap and very powerful disinfectant, dangerous to use on account of its being colourless, and a very deadly poison; the object of mixing the above ingredients with it is to tint it and make it offensive, so as to avoid mistake.

Formaldehyde and Formalin. Coal-tar is the original source of most of the patented disinfecting liquids which are on the market. One of the most powerful disinfectants is that known as formaldehyde. It is generally supplied to the public in the form of solution containing 40 per cent. of formaldehyde, the solution being known as formalin. In the same way that the destructive distillation of coal produces coal-tar, so a similar treatment of wood produces wood-tar. In both cases other materials are produced, including, in the latter case, what is known as wood

naphtha or methyl-alcohol, from which, by an oxidising process, the formaldehyde is produced. The use of formaldehyde is apt to produce a painful irritation of the skin and nails, and it is very desirable, therefore, to prevent the hands being wetted by it.

Use of Heat and Steam. In the case of articles of small value, the safest way is to burn them, but disinfection may also be secured by exposing them to either dry or moist heat. Exposure to hot air at a temperature of 284° F. for four hours is about equal to the effect of exposure for five minutes to steam at a temperature of 212° F. Steam is therefore much more largely used.

Steam Disinfectors. There are many forms of steam disinfecting apparatus. One of the oldest and best known is the "Washington-Lyons". The disinfecting chamber is of oval section, encased by a steam jacket, the outer casing being covered with asbestos to assist in retaining the heat. The apparatus is built into a wall which divides a large room into two, and which has no door or other means of communication except a fixed window, through which signals can be given. The infected articles are brought into the room on one side, hence distinguished as the "infected" side, and are put in a cradle or hung on hooks in a light frame on wheels, which is then run into the disinfecting chamber and the door closed and strongly screwed up, a rubber joint making it airtight. Steam, at a pressure of 30 lb. to the square inch, and a temperature of 273° F., is then turned into the outer jacket, so as to raise the temperature of the inner chamber high enough to prevent condensation of the moisture, from the clothes, etc. Next, the air is exhausted from the chamber as far as possible, to give space for the steam. This is done by the suction caused by a jet of steam passing over a pipe, with a high velocity, a two-thirds vacuum being obtained in about ten minutes. Steam is then admitted for ten minutes, until a pressure of 30 lb. per square inch is registered, corresponding to a temperature of about 250° F. It is then shut off to see if the pressure gauge shows any fall, due to particles of steam condensing; if so, steam is turned on again until the pressure remains constant. In bad cases, the steam is turned on a second time for a further ten minutes.

After the steam is cut off, dry air is passed in through tubes on which steam is playing, in order thoroughly to dry the articles, the cradle being then drawn out through the opposite door of the apparatus, or the "clean" as opposed to the "infected" side of the disinfecting station. The whole process takes from thirty-five to forty minutes.

Great care has to be exercised in regulating the temperature, as

the sanitary authority disinfecting is held liable for any damage done to the articles.

It is essential that saturated steam should be used, superheated steam having little greater power of penetration than hot air. Saturated steam is water vapour at the boiling temperature which is normal to the prevailing pressure. Superheated steam is steam whose temperature has been increased above the boiling-point by passing it through a coil in a furnace, in which form it behaves like other gases.

There are a large number of patterns of steam disinfector, and it is difficult to say that one is better than another. One of rather a different type from that just described, however, is the "Thresh" disinfector. In this, the lower part of the enclosing jacket of the cylinder acts as the boiler, and has a small furnace under it. The steam passes continuously through the disinfecting chamber, escaping up a chimney, and so is not under pressure, as in the case of the Washington-Lyons apparatus. Heated air is then admitted and the articles thus rapidly dried.

Infected articles should be brought to the disinfecting station in proper vans, lined with iron and airtight, kept solely for the carriage of infected articles, separate vans being used for carrying away the clean articles and kept for that purpose only.

Public Disinfecting Stations. A public disinfecting station consists principally of two rooms, the infected and disinfected side, separated by a wall with no possibility of the passage of air from one to the other, such as a door or opening window. The apparatus is built into this wall. The van used for the carriage of infected goods should be housed at the infected end of the building, and the clear van at the other end. An incinerator, or small refuse destructor, should be installed at the infected end for the destruction of things which are too filthy to clean. Bedclothing and similar things require to be soaked in water and washed before passing through the disinfector, as the steam would fix the stains permanently. It is therefore usual to install a certain amount of laundry apparatus, such as a washer, hydro-extractor (or centrifugal wringer), drying chamber and mangle, etc.

Some things cannot be subjected to steam at all. It is therefore a good plan to provide a formalin chamber, that is to say, a room kept exclusively for submitting articles to the action of formaldehyde gas, generated by special types of lamp.

Verminous Persons. Bathrooms should be provided, one for men and one for women, for the cleansing of verminous persons. The bathrooms should adjoin the infected room, and have special

hoppers, locking each side, in which the person can place his clothes, which are then put through the disinfector and made fit for use again.

In some cases, a bottle-washing room is added with special washing machines, sinks, etc.

It perhaps need hardly be said that any such building should be exceptionally well lighted and ventilated, and that the walls and floors should be jointless and non-absorbent, the walls being preferably of glazed tiles to facilitate cleansing. All angles should be rounded, with the same object.

Disinfection of Living Rooms. We come next to the disinfection of rooms. This can be done in many ways. Assume sulphur dioxide is to be used: Open all cupboards, drawers, boxes, etc., saturate the walls, floor and woodwork with water, and seal up all openings, such as fireplace, windows, doors and ventilators, with brown paper. Place the sulphur on a tin plate, say 2 lb. to every 1000 cubic feet of space and support it in a larger vessel containing water, to guard against fire. Put this in the middle of the room, ignite the sulphur, and make a speedy exit. Shut the door and seal it up by pasting strips of paper round. Leave the room thus for twenty-four hours. Then open the doors and windows, strip the paper off the walls and burn it, wash off the ceiling with limewash, and scrub the floor and all woodwork, furniture, etc., with a solution of perchloride of mercury, 1 part to 1000 parts of water.

The sulphur dioxide can also be obtained in tins under pressure, which is a convenient form, as all that is necessary is to cut off the top of the tin and allow the gas to escape. Gilt picture frames, or steel goods, should not be allowed to remain in the room, as the sulphur spoils them.

Formaldehyde is largely used for the fumigation of rooms, being either vaporised by means of special lamps, or sprayed over the surfaces of walls, ceilings, floors, etc.

Vapour-producing Lamps and Sprays. Many forms of lamp and spray have been introduced, but it is deemed beyond the province of this volume to deal with them. Some important experiments in reference to the spraying of disinfectants were carried out by Drs. Thresh and Lowden, who arrived at the following conclusions:

1. That for spraying to be efficient, every portion of the surface to be disinfected must be thoroughly moistened with the disinfecting solution; merely passing the spray into a room and trusting to its settling upon the surfaces is utterly unreliable.

2. The whitewashed surfaces require particular attention, being far more difficult to disinfect than surfaces of wood and paper.

3. That solutions containing under 2 per cent. of formaldehyde are not absolutely reliable. Solutions, therefore, of not less than these strengths should be used.

4. That a proper spray, properly used, effects room disinfection in the minimum of time and with the minimum of expense, and is more reliable than disinfection by sulphur or formalin vapour.

Some of the forms of disinfecting lamp are arranged so that they can, if desired, work from the outside of the room by spraying through the keyhole.

Hydrocyanic Gas for Disinfection and Disinfestation. Hydrocyanic acid gas, which in solution is commonly known as prussic acid, is a most effective means of fumigation, and destroys bacteria, vermin, bugs, lice and even the eggs of bugs, etc. It does no damage to metal, wood or paintwork, is relatively cheap and there is no danger of fire. The disadvantage of the method is that it is a most deadly poison, so that its application needs skilled operators and the evacuation of the house on either side. The destruction of pests (or "Disinfestation") is often particularly important, owing to the diseases which many of them carry, and in this connection, insects such as flies, bugs, lice, beetles, etc., can be conveniently dealt with by a dust or spray containing D.D.T. or by a dust, fumigation or spray of Gammexane, both of which have a valuable residual action lasting some weeks and which act by paralysis rather than direct poison.

Smoke Abatement. Another point which may be just referred to under the heading of drainage and sanitation is that of smoke abatement.

In large boiler furnaces the chief cause of smoke is improper stoking and an insufficient air supply. If the furnace is regularly stoked with small quantities of fuel at short intervals, and is provided with proper draught, either natural or forced, there should be no nuisance. The chimney should not, in fact, be looked upon as solely intended to let the smoke out, its main purpose being to produce a draught through the furnace and assist combustion.

As the hot gases rise up the chimney, air must enter the furnace to take their place. If a forced draught is used injudiciously, it is apt to be productive of considerable smoke, but forced-draught systems should be capable of regulation, and be put in the hands of competent stokers.

At the time of writing (July 1956) it seems likely that the Clean

Air Act 1956 will become law. Before this there were about nineteen local authorities in this country who had taken powers under local acts of parliament to establish "Smokeless Zones" and about forty who had obtained lesser powers under local acts to control smoke from industrial chimneys. These powers generally excepted smoke from domestic chimneys and required industries to abstain from emitting dark smoke only "as far as practicable" and gave many loopholes.

The Clean Air Act would give all local authorities, by "Order", and without a local act, powers to designate "Smoke Control Areas", and prohibit the emission of dark smoke from the chimneys of any building (industrial or domestic) in the zone, unless specifically excepted.

Such "Orders" require confirmation of the Minister. In "designated areas" owners or occupiers of existing private dwellings could apply for grants towards the cost of adapting or replacing grates and stoves so as to enable smokeless fuel (gas coke, hard coke, Phurnacite, anthracite, Welsh dry steam coal, Coalite and Rexco) to be used.

Useful information on smokeless zones and the appliances and fuels conducive to clean air is available from the Solid Smokeless Fuels Federation (S.S.F.F.), 74, Grosvenor Street, London, W.1.

Domestic Fireplaces. In the case of domestic fireplaces, the details given as to their construction in Chapter V should be carefully followed; that is to say, briefly, the fireplace should be almost entirely of firebrick, with a minimum of iron. The stoking should be regular; one should not let the fire go almost out and then heap it up with coal; such a procedure is bound to lead to smoke, not necessarily in the house, it is true, but every such addition helps to pollute the air of our towns.

Further improvement might be made by the provision of better linings to chimney flues. They are often of very rough construction and not properly parged and cored in order to leave a free passage through them. The use of unglazed tubes of clay ware for lining flues is no new idea, and has much to recommend it.

CHAPTER XVI

Legal Notes

Purpose of the Chapter. This chapter is intended to give a general idea of the legal position with regard to sanitary work. It does not profess to give qualified legal opinion upon specific points. Persons who require this should consult the statutes, the Local By-laws or the Regulations concerned. Books written by lawyers on "Public Health Law" or on Model Building By-laws may help still further, but if these fail to elucidate the matter reference should be made to a member of the legal profession for guidance on the matter in hand.

Differing Forms of Legal Control. Building and sanitary work may be affected by general statutes, by Local Acts, sometimes (a little) by Common Law, while as regards use of materials, special sizes and types of fitting and arrangement in detail, by Local By-laws. In some cases "orders" or "Regulations" are authorised by an act of Parliament to provide further detailed control.

"Model By-laws" have been referred to quite a lot in the preceding chapters, but these are not actual law. As their name would suggest, they are just a specimen set of by-laws, prepared by the Ministry of Housing and Local Government as a guide to help the local authorities in the compilation of their own local building and drainage by-laws, which, when they have been agreed to in Council, are submitted to the Ministry, and if considered satisfactory, are then "sanctioned" and they become local law. The local by-laws are just as binding on the building owner as statute law, but the penalties for breach are usually much more limited than would be the case with Statute Law.

Statute Law. The law relating to sanitary matters, broadly, is embodied in Acts of Parliament, the provisions of which are administered by local government authorities.

County and County Borough Councils. The oldest unit of local government in England and Wales is the parish, but the powers and duties of parish councils and parish meetings have been almost wholly transferred by statute to bodies controlling larger areas.

It is unnecessary here to trace the course by which our present local government system has been evolved and it is sufficient to say that the existing system is now defined by the Local Government

Act, 1933, a consolidating Act, which repealed and re-enacted, with amendments, the provisions of Local Government Acts and other statutes of earlier days.

All England and Wales are divided into administrative counties and county boroughs, which are governed by county councils and county borough councils respectively. The administrative counties are not in all cases the same as the geographical counties, for some of the latter are divided into two or more counties for administrative purposes, whilst the county boroughs are excluded from the counties in which they are to be found in an atlas, and have most of the powers possessed by the administrative counties.

Only the larger of our boroughs are county boroughs. The minimum population necessary to justify the elevation of a borough to the status of a county borough was formerly 50,000, but is now 100,000.

Boroughs, Urban Districts and Rural Districts. Every administrative county is divided into county districts; these are either boroughs, urban districts or rural districts. The boroughs are those county districts which have been incorporated as boroughs by Royal Charter.

The boundaries of counties, boroughs, urban and rural districts can be changed by an order of the Boundary Commission, set up by the Local Government (Boundary Commission) Act, 1945, but any such order made for a county or county borough needs confirmation by Parliament.

Little need be said here as to the powers and duties of county councils, but it will not be out of place to mention that they are responsible for the construction and upkeep of all roads in rural districts and of all classified roads in non-county boroughs (i.e. boroughs which are not county boroughs) and in urban districts; also, that they have a considerable measure of control over the county district councils and the power to make those councils perform their duties, the measure of such power being to some extent dependent on the status of the district council—whether it is urban or rural—and upon its population.

It is, however, with the county borough councils, borough councils, urban district councils and rural district councils with whom we are most concerned, for it is these bodies who make and administer building and drainage by-laws, provide schemes of main sewerage and sewage disposal, collect and dispose of refuse, cleanse streets, disinfect houses and articles, and take the necessary steps against persons who cause nuisances of a sanitary nature. These bodies we shall refer to as "local authorities".

Special Law for London Area. The position in London is somewhat different, for the Local Government Act, 1933, does not, generally speaking, apply therein. The Local Government Act, 1888, however—the Act which first established the administrative counties—made a county of London, or rather of such parts of the metropolis as were then built up, whilst the London Government Act, 1899, divided the county into metropolitan boroughs. The City of London is one such borough, but, being of far more ancient origin than either the county or the other boroughs, it has some special privileges and duties.

The distribution of duties between the London County Council and the Metropolitan Borough Councils is in some respects different from that in operation elsewhere in England and Wales, for we find that within the County of London it is the county council who are responsible for main sewerage and sewage disposal, and for making by-laws, whilst the borough councils administer the sanitary and building by-laws and are responsible for street maintenance.

Principal Statutes dealing with Sanitary Matters Outside and Inside London. The legislation which deals with streets, buildings and sanitation in the County of London differs from that in force in the remainder of the country.

Outside the metropolis all matters relating to streets are to be found in the Public Health Act, 1875, its Amendment Acts of 1890 and 1907, the Public Health Act, 1925, and the Private Street Works Act, 1892. The Public Health Act, 1936, deals with buildings, drains, sewers and sanitation generally.

Within London the most important statutes in force are: the London Building Act, 1930, and its Amendment Acts of 1935 and 1939, which deal with building work and the laying out of new streets; the Metropolis Management Act, 1855, and its numerous Amendment Acts (the chief of which is that of 1862), which deal with the making up of streets and similar matters; the Public Health (London) Act, 1936, which deals with drains, sewers and sanitation generally.

It is with the two Acts of 1936 that we are most concerned, and it will be found that their provisions are in most respects very similar; there are, however, some important respects in which they differ and these will be noticed in due course.

Definition of "Drain". We shall begin with the subject of drains and sewers.

In the Public Health Act, 1936, a "drain" is defined as meaning a drain used for the drainage of one building, or of any buildings

or yards appurtenant to buildings within the same curtilage. It may be noted that there has been much questioning as to the meaning of the word curtilage; Mr. Macmorran, K.C., in his well-known work on the "Law of Sewers and Drains", defined it as the land adjoining a building and which would pass with it, on a conveyance, so far as is necessary and convenient for its use.

Definition of "Sewer". The definition of "sewer" in the same Act is that it does not include a drain as defined above but, save as aforesaid, it includes all sewers and drains used for the drainage of buildings and yards appurtenant to buildings. It would seem then that, to express the matter more simply, a sewer is a pipe used for the drainage of two or more buildings not in the same curtilage; but it seems also that it may include pipes used only for the drainage of roads, for the Act does not say that a sewer *means* sewers and drains used for the drainage of buildings, but that it *includes* such sewers and drains; it therefore presumably may also include pipes not used for the drainage of buildings and it is clear from certain other sections of the Act that it is intended to do so.

Public and Private Sewers. Sewers may be either "public sewers" or "private sewers" under this Act. In effect a "public sewer" is a sewer which vests in (i.e. belongs to) a local authority and a private sewer is one which does not. The question, however, then arises as to what sewers belong to a local authority and the answer to this is by no means simple. The following sewers will belong to a local authority:

(*a*) Sewers which they have constructed at their own expense or have acquired, whether they are situated inside the district of the local authority or not (for it is quite common for urban authorities to construct their sewage-disposal works in an adjoining rural area and to construct an outfall sewer thereto).

(*b*) All sewers constructed to the satisfaction of the local authority as private street works, except sewers constructed only for the drainage of roads which will be repairable by the county council.

(*c*) All "combined drains" constructed prior to the 1936 Act for the joint drainage of two or more buildings under the provisions of earlier Acts. In this case, however, the local authority can recover the cost of maintenance and repair from the owners of the premises served.

(*d*) All new sewers which the local authority may declare to be vested in them. The Act provides, however, that, if the owner of any such sewer objects to its adoption by the local authority, he may appeal to the Minister of Health, who may allow or disallow the proposal; if he allows it he may direct that compensation shall

be paid. Any person who was entitled to use the sewer at the date of its adoption may continue to use it afterwards.

A "private sewer" is any sewer which is not a public sewer. It will therefore include:

(*a*) Pipes laid after the commencement of this Act for the joint drainage of two or more buildings, not in the same curtilage.

(*b*) Sewers laid for the development of building estates, not yet adopted by the local authority as public sewers.

It should be noted before we pass on that the question of whether a pipe is a public sewer, private sewer or drain does not depend in any way upon whether it is placed in public or private property; public sewers can be, and often are, laid in private land, for the local authority has the power to lay a sewer in any land after reasonable notice, whilst the lower ends of private sewers and drains are usually in public streets.

In the London Act the definitions are somewhat different; for the term "drain" includes not only a drain used for the drainage of one building, or premises within the same curtilage, but also a drain for draining a group or block of houses by a combined operation under an order of a borough council or their predecessors, whilst a "sewer" means a sewer or drain of any description except a drain as defined above. In London there is no such thing as a private sewer; sewers constructed by the county council, or which belonged to them at the passing of the Act, or which they shall declare to be vested in them, shall belong to the county council, while all other sewers shall belong to the borough council in whose district they are situated. In general the main sewers will vest in the county council and subsidiary sewers in the borough council.

Duty of Cleansing and Repair of Drains and Sewers. The importance of these definitions lies, of course, mainly in the fact that the duty of cleansing and repair of any drain or sewer is upon the person or body in whom it is vested.

In the provinces (i.e. outside London) it is the duty of every local authority to provide such public sewers as will be necessary for effectually draining their district, and such sewage disposal works as are needed. It should be noted, however, that the Act does not say that the local authority must provide sewers at their own expense in anticipation of future building developments; the normal procedure in estate development is for the owner to lay the sewers which are necessary for estate drainage and for these to be adopted by the local authority as public sewers, either immediately after construction or when adopting the street as a public street, after the execution of private street works. It

should be noted also that there is no obligation to provide a sewer for every house; isolated houses in rural areas are commonly drained to cesspools.

Position in London. Similarly, in London, it is the duty of the borough council to make such sewers as are necessary for draining the borough effectually and for the county council to construct such sewers as are necessary for the main drainage of the county.

Where a person proposes to construct a private sewer or drain and the local authority consider that it would be an advantage for it to form part of the general sewerage system of the district, they may require it to be formed of such materials, size, depth, gradient and direction as they may specify. The owner may appeal against the requirements to the Minister of Health and (whether he appeals or not) is entitled to be reimbursed any additional expense to which he is put. No such provision is contained in the London Act, but a borough council may contribute towards expenses incurred by an owner or occupier in constructing a sewer in the borough for the drainage of his premises; presumably they would not do so unless it were of some general use.

The local authority (in London or elsewhere) may alter or discontinue any public sewer, but if any person is thereby deprived of its lawful use he must be provided with a sewer equally effective and the local authority must do such alteration to the drains as is required at their own expense.

Every local authority, outside London, shall keep in their offices a map showing the public sewers of their district, distinguishing between surface water and foul sewers if both are in existence.

Petrol and Other Harmful Solids or Liquids. In both Acts there are clauses imposing penalties, on conviction, for putting or passing into sewers solid or liquid matters which might cause obstruction to the flow or cause danger to health. Persons allowing petrol or similar inflammable substances to pass into sewers are similarly liable to penalties.

Rights of Adjoining Owners and of Local Authorities. Owners and occupiers of premises are entitled, as a right, to branch their drains and private sewers into the appropriate public sewer, provided they give notice to the authority and comply with their regulations as to the manner of making the connection. Outside London the authority may, if they wish, themselves make the connection at the cost of the owner. In some few cases it may be more convenient to branch a drain or private sewer into a public sewer of an adjoining district; the owner of the drain or private

sewer may do this, but the authority who own the public sewer may make a charge, which may be defrayed by the authority of the district in which the premises are situated. Local authorities outside London may, under the Public Health (Drainage of Trade Premises) Act, 1937, impose conditions as to the nature, composition and rate of discharge of trade effluents, and may make by-laws regulating such discharge.

Where (in the provinces) plans are deposited for the erection or extension of a building and it is proposed to build over any sewer or drain which is shown on the map of sewers, the authority shall reject the plans unless they are satisfied that they can properly consent; in London any person who knowingly builds over a sewer without consent is liable to penalties.

Law Relating to House Drains. The law relating to the provision of house drains differs considerably for London and the provinces.

In the provinces, where an owner wishes to erect or extend a building and submits plans in accordance with the by-laws, the authority shall reject the plans if these do not show satisfactory proposals for drainage and drainage cannot in the opinion of the authority be dispensed with. The authority can insist on the drains being connected to a sewer, rather than to a cesspool, if (*a*) the sewer is at a reasonable level, (*b*) the intervening ground is land through which the owner is entitled to lay a drain, and (*c*) the sewer is within 100 feet of the building, or the authority agree to bear the excess of cost due to the distance exceeding 100 feet.

Common or Joint Drains. Cases often occur where two or more buildings can be more cheaply drained by a common pipe than by separate drains. The authority will be within their rights if they insist on separate drains, but they can require combined drainage by a private sewer, constructed by the owners or by the authority on their behalf.

Where an existing building in the provinces has no satisfactory drains, or the drainage is defective, the authority may require drains to be laid, or such other work done as is necessary to meet the case. If they require the construction of drains, they can order that these shall be connected to a sewer in the same circumstances as in the case of new buildings.

House Drain Law in London. In London it is unlawful to erect or occupy a new building unless a drain has been provided to the satisfaction of the borough council, of such materials, size, level and gradient as the council may direct; such drain shall lead to a sewer if there is one within 100 feet of the building. It may be noted that this section of the Act says nothing about the sewer

being "at a reasonable level", the intention clearly being that new buildings should be erected at such levels that drainage to a neighbouring sewer is possible from the lowest floor thereof. When a house is to be rebuilt, after it has been pulled down to the level of the ground floor, its level must be raised if this is necessary for its drainage to the sewer, unless such a proposal would be impracticable, in which case the council may allow the installation of pumping or lifting appliances, or may allow part of the building to be so constructed that drainage is not required therefrom.

If any existing building in London is without a sufficient drain, emptying into a sewer, and a sewer of sufficient size is within 100 feet of some part of the building and at a lower level than the building, the borough council can require the owner to construct such a drain to the sewer and to provide proper paved surfaces for carrying surface water to the drain, sinks, and other necessary apparatus. If, again, any building is without a sufficient drain and there is no sewer within 200 feet of the building, the council may require the owner, as a temporary measure, to construct a drain leading to a cesspool. The Act is curiously silent as to what is to be done if there is a sewer within 200 feet of the building, but not within 100 feet.

The regulations of local authorities usually stipulate that work involving the disturbance of public roads and footpaths shall be done by them at the expense of the owner or occupier. Both in London and in the provinces the authority, on payment of the cost thereof, may undertake the connection of drains to sewers, or do any works of drainage on behalf of the owners of buildings.

Maintenance of Drains and Sewers. We now turn to the subject of the maintenance of drains and sewers. Drains and private sewers are in all cases maintainable by their owners, whilst the local authority has the duty of maintaining public sewers; there are, however, some circumstances in which a provincial local authority can recover the cost of maintaining certain public sewers from the owners whose premises are served by those sewers.

The circumstances in which this is the case are:

1. Where the sewer in question was, before the passing of the Public Health Act, 1936, a "combined drain", which under earlier legislation was repairable by the owners of the premises served by that drain.

2. Where the sewer was not constructed at the expense of the authority and lies in a garden, court or yard belonging to any of the premises served by the sewer (or to any of them in common), or if it lies under a building comprised in any of those premises,

or in a way used as a means of access to those premises, not being a public highway.

In any case where the authority are entitled, as stated above, to recover the cost of maintenance of a public sewer from the owners of premises served by the sewer, they must apportion the cost fairly among those owners, having regard to all the circumstances of the case, such as the benefit derived by each, the distance for which it is laid in the land of each, the point at which the work was necessary and the responsibility for any act or default which made the work necessary.

If, instead of executing works of maintenance to any such sewer as we have been referring to immediately above, the authority enlarge or otherwise improve it, so that it may serve additional premises, they may recover from the owners whose premises are now being served only such an amount as would be reasonable for maintenance and the owners are then relieved of all future liability.

No person shall reconstruct, alter or repair any drain without notice to the authority, except in emergency, in which case he shall not cover up the work without notice; he shall permit an officer of the authority to have access for inspection.

If the drains of a building, outside London, are sufficient and effectual for their purpose, but are not adapted to the general sewerage system of the district, the authority may close such drains on the condition of providing, at their own expense, other drains as sufficient and effectual for the premises in question.

Sanitary Accommodation. As to sanitary accommodation, it is provided in the Public Health Act, 1936, that, where plans are submitted for a new building or the extension of a building, the authority shall reject the plans if these do not show sufficient and satisfactory closet accommodation and the authority do not consider it can be dispensed with; if there is a water supply and sewer available the authority can require the closets to be water-closets. In the case of existing buildings, if it appears to the authority that there are not sufficient closets, or that those which are provided are in an unfit state and cannot be made fit without reconstruction, they can require the owner to provide water-closets, if there is a water supply and sewer, and in other cases can require him to provide earth-closets. If the present appliances are unfit, but can be made fit without reconstruction, they can order him to do what is necessary. If the present accommodation is in satisfactory condition, but is not a water-closet and a water supply and sewer are available, the authority can require it to be replaced by a water-closet but must bear half the cost of the conversion.

The provisions of the Public Health (London) Act, 1936, in respect of this matter of sanitary accommodation are, in substance, almost the same as those of the provincial Act; the appliance must ordinarily be a water-closet, earth-closets or privies being allowed only if sewerage or a sufficient water supply are not available. There is no mention of conversion of earth-closets to water-closets, but presumably the borough council can require this to be done by the owner at his own cost if a sewer and water supply are, or become, available.

Sanitary Accommodation in Factories. All factories, workshops and workplaces must have sufficient sanitary accommodation with proper separation of the sexes. In connection with this, the Home Office has issued an order under the Factory Acts defining adequate accommodation as meaning one closet for every 25 women employed; for men, one for every 25 employed up to 100, and beyond that figure one for every 40 men, if in addition sufficient urinals are provided. In large works, where more than 500 men are employed, the number of closets may be reduced to one for every 40 men if a proper system of control is adopted and urinals are also provided.

Powers to Insist on Sanitary Conditions in Certain Cases. The following miscellaneous provisions are also to be found in the Public Health Act, 1936:

No room, any part of which is over a closet (other than a water-closet or earth-closet) or over a cesspool or ashpit, shall be occupied as a living-room, sleeping-room or workroom.

The occupier of every building in which there is a water-closet shall cause the flushing apparatus to be kept supplied with water and protected from frost; in a building which has an earth-closet it shall be kept supplied with dry earth or other suitable deodorant.

When plans are deposited for the erection or extension of a building and the site has been filled in, or covered with, material impregnated by offensive animal or vegetable matter, the authority shall reject the plans unless they are satisfied that the material has been removed or has become innocuous. The person who deposited the plans has the right to appeal to a Court of Summary Jurisdiction against their rejection.

The authority may require the owner to pave and drain any court, yard or passage which gives access to any house or joint access to two or more houses.

The authority may require any leaking or overflowing cesspool to be remedied by the person in default.

A parish council, or a local authority, may deal with any pool,

ditch, gutter or place containing filth, stagnant water or other matter likely to be prejudicial to health, by draining, cleansing or covering it, provided they do not interfere with any private right or with any public drainage, sewerage or sewage disposal works, and may execute any incidental works; they may, alternatively, contribute towards the expenses incurred by others in so doing. This power does not in any way prejudice the right of the local authority to take action if it is a statutory nuisance.

Offensive Pools, Ditches, etc. In London the borough councils have similar powers either to deal with such offensive pools, ditches, etc., themselves or to call upon the person who caused the nuisance, or the owner or occupier of the premises, to do what is necessary, in which case the council may defray all or any part of the cost; if, however, such action is prejudicial to any water rights the council must either pay compensation or acquire the rights.

If a local authority, outside London, make complaint against another local authority that a water-course or ditch, at or near the boundary between their districts, is foul and offensive, a Court of Summary Jurisdiction, of the district in which it is situated, may make an order for its cleansing and for the execution of any work; the order shall state who is to do the work and by whom the cost shall be paid.

If a provincial local authority consider that a water-course or ditch (not necessarily offensive), situated on or adjoining land laid out for building, ought to be filled or culverted, they may require the building owner to do this before or during the building operations, and to provide all necessary gullies. Any question of the reasonableness of the authority's requirements shall be determined by a Court of Summary Jurisdiction. The building owner, however, cannot be required under this section to execute work on someone else's land unless that person consents.

Culverting of Streams Require Approval by Local Authority. No person shall culvert any stream except in accordance with plans and sections approved by the authority, but such approval shall not unreasonably be withheld and there is the usual right of appeal to a Court of Summary Jurisdiction against the authority's requirements.

The owner or occupier of any land shall maintain and cleanse any culvert in such land.

The authority may, if they think fit, contribute the whole or part of the expenses incurred, on works in connection with the above-mentioned provisions relating to water-courses, culverts,

etc., or may, by agreement with the owner or occupier, execute such works.

The owner or occupier of any land shall maintain and cleanse any culvert in such land.

The authority may, if they think fit, contribute the whole or part of the expenses incurred on works in connection with the above-mentioned provisions relating to water-courses, culverts, etc., or may, by agreement with the owner or occupier, execute such works.

Collection and Disposal of House Refuse. We now come to the subject of the collection and disposal of refuse, street cleansing and similar matters.

Under the Public Health Act, 1936, a local authority may, and if required by the Minister shall, perform any or all of the following services:

(*a*) The removal of house refuse; (*b*) the cleansing of earth-closets, privies, ashpits and cesspools.

If they have undertaken any of these duties and fail to perform them within seven days of a notice from the occupier of any premises, the occupier may recover a sum of five shillings per day during such default.

When an authority have undertaken the duty of removing house refuse they may make by-laws imposing duties on the occupiers for facilitating the collection, requiring the use of bins provided by the authority and regulating the use of the bins.

If they have not undertaken that duty they may make by-laws requiring occupiers to remove their refuse at specified intervals and to cleanse their earth-closets, privies, ashpits and cesspools.

A local authority may, but cannot be compelled to, undertake the removal of trade refuse; if they do so they must make a charge. Where they have undertaken the duty and fail to fulfil it, after seven days' notice, the occupier may recover the sum of five shillings per day during the default.

Any dispute as to whether any particular refuse is house or trade refuse, or as to the reasonableness of their charges for removing the latter, shall be determined by a Court of Summary Jurisdiction. It may be noted here that the Superior Courts have held that the question of whether any particular refuse is house or trade refuse depends, not on the nature of the premises from which it is collected, but on the nature of the refuse itself. Thus, if the refuse is of a kind ordinarily removed from dwellings, it is house refuse even if produced on trade premises.

An authority who undertake the removal of house refuse may, by notice, require the owner or occupier of any buildings to provide such number of covered bins, of such material, size and construction as they may approve. They cannot, however, require the replacement of any existing bin, if this is of satisfactory design and in good condition. Alternatively, the authority may provide bins and make an annual charge for their use.

In London the borough councils *must* remove house refuse and cleanse earth-closets, privies and cesspools, and are liable to a fine of twenty pounds if they fail to do so, without reasonable excuse, after forty-eight hours' notice from an occupier. The councils *must* also remove trade refuse if required to do so by the owner or occupier, but shall make a reasonable charge.

Street Cleansing. In the country, a local authority may, and if required by the Minister of Health shall, undertake the cleansing of streets and may undertake the watering of them.

In both London and the country the local authorities, having collected refuse from premises and streets, may dispose of it in such manner as they think fit.

"Nuisances" Defined. The next matter to be considered is what are termed "statutory nuisances". The term "nuisance" at law means anything which causes hurt or annoyance, and a person who suffers from a nuisance committed by another may bring an action in tort; but there are certain particular kinds of nuisance in respect of which a local authority can proceed in the public interest; these are named in Acts of Parliament and hence are termed "statutory" nuisances.

The most important examples, from our point of view, under the Public Health Act, 1936, are:

(*a*) Any premises in such a state as to be prejudicial to health, or a nuisance.

(*b*) Any animal kept in such a place or manner as to be prejudicial to health, or a nuisance.

(*c*) Any accumulation or deposit which is prejudicial to health, or a nuisance.

(*d*) Any well, tank cistern, or water-butt used for the supply of water for domestic purposes, if constructed or kept so that the water is liable to contamination prejudicial to health.

(*e*) Any pond, ditch, water-course, etc., so foul as to be prejudicial to health, or a nuisance.

Under the Public Health (London) Act, whilst the list is not precisely the same, it is substantially similar; but in London an occupied house without a proper and sufficient supply of water is

to be dealt with as a nuisance, as also is the absence of water fittings in a house.

Abatement of Nuisances. It is the duty of every local authority, under the Public Health Act, 1936, to inspect their district from time to time for the detection of statutory nuisances. If they discover one they shall serve on the person who caused it an "abatement notice", or, if they cannot find that person, on the owner or occupier of the premises in which it occurs; the notice will require him to abate the nuisance and to execute any works which may be necessary for that purpose. It is provided, however, that, when the nuisance is due to structural defects, the notice shall be served on the owner; also that, when the offender cannot be found and the nuisance is clearly not caused by the act or omission of the owner or occupier, the authority may themselves abate it.

If the person on whom the notice is served does not comply with it, or if the nuisance is likely to recur, the authority shall apply for a summons for such person to appear before a Court of Summary Jurisdiction. If, on the hearing of the case, it is proved that the nuisance exists, or is likely to recur, the Court shall make a "nuisance order" directing the offender as to what he is to do; the Court also may impose a fine and may award costs to the authority. They may also prohibit the use of the building for human habitation if the nuisance is causing it to be unfit for such habitation.

If the person on whom the nuisance order is made does not comply with it he is liable to a further fine, and the authority may do what is necessary in execution of the order and may recover from him the cost of doing so.

It is provided, however, that proceedings shall not be taken if the nuisance was necessary for the effectual carrying on of a business or manufacture and the best practicable means have been taken to prevent its being prejudicial to health or an annoyance to the neighbouring inhabitants.

When a nuisance appears to be caused by two or more persons proceedings can be taken against any or all of them, and the order of the Court may be directed to any or all of those proceeded against. If some of the offenders were not proceeded against, those who were can recover from them a due share of the expense incurred and of any fine imposed.

An appeal against a nuisance order of a Court of Summary Jurisdiction and, in fact, against almost any other order of such Court under this Act, can be made to a Court of Quarter Sessions.

The procedure for requiring the abatement of nuisances in London is substantially the same as in the provinces.

Where a local authority, outside London, have reasonable grounds for believing that any sanitary convenience, drain, private sewer or cesspool is in such a condition as to be prejudicial to health or a nuisance, or that a drain or private sewer is so defective as to admit surface water, they may examine its condition and for that purpose may apply any test, other than a water test, and may open up the ground if necessary. If on examination the appliance or work is found to be in good order they must reinstate the ground as soon as possible and make good any damage. If the examination shows the appliance or work to be in bad order they have ample powers under other sections of the Act to require the matter remedied.

It may be mentioned here that an officer of the authority has the power to enter any premises, on proving his identity, for the performance of any of his duties under the Act or by-laws, but shall give twenty-four hours' notice to the occupier of his intention, if the premises are other than a factory, workshop or workplace. If it can be shown that admission is refused, or that the premises are unoccupied, or that the matter is urgent, or that notice of entry would defeat the object of entry, a Justice of the Peace may by warrant authorise entry, if need be by force.

Similar powers are given by the London Act, but the works which may be examined include also any water supply, sink, trap, siphon, pipe or other works or apparatus connected therewith, and in cases of urgency the officer can enter without notice without obtaining a warrant.

Local Building and Drainage By-laws. Detailed requirements as to the design and construction of new drainage systems and of all kinds of sanitary fittings, as well as to the construction of new buildings, will be found in the local by-laws. A by-law is a law, of purely local application, made by a local authority under power conferred by statute and confirmed by a Government Department (the Ministry of Housing and Local Government for all building and sanitary by-laws). In order that it shall be valid a by-law must be (1) *intra vires*, i.e. within the powers conferred by statute; (2) certain in its terms, i.e. not ambiguous; (3) not repugnant to the law of the land; and (4) reasonable. The fact that a Government Department has confirmed a by-law will not make it valid if it is contrary to any of these four requirements.

The by-laws will to some extent vary in different districts, but in general will be very similar to the Model By-laws issued by the

Ministry of Housing and Local Government. A fully illustrated explanation of these will be found in the book "Model Building By-laws", by G. E. Mitchell, published by B. T. Batsford, Ltd.

Whilst, in general, by-laws apply only to new buildings, some of them may be applied to structural alterations and to existing buildings, where these are converted to dwelling-houses or become occupied by two or more families.

Definition of "Owner". We must not conclude these notes on sanitary law without explaining what is meant by an "Owner" in the Public Health Acts.

The Public Health Act, 1936, defines owner as "the person for the time being receiving the rack rent of the premises, whether on his own account or as agent or trustee for any other person, or who would so receive the same if the premises were let at a rack rent". The definition in the Public Health (London) Act, 1936, is substantially the same.

The two Acts, however, have different interpretations of the words "rack rent". In the provincial Act it is a rent not less than two-thirds of the full net annual value; i.e. "a rent which is not less than two-thirds of a rent at which the property might reasonably be expected to let from year to year, free from all usual tenants' rates and taxes, and tithe rent charge (if any), and deducting therefrom the probable average annual cost of repairs, insurance and other expenses (if any) necessary to maintain the same in a state to command such rent". In the London Act rack rent is a rent not less than two-thirds of the "annual value", without any reduction for repairs and insurance.

A fact worth notice is that, under the wording of these definitions, agents and trustees rank as owners, and are therefore personally liable for the obligations of owners under the Acts.

There is, however, some protection given to them under the provincial Act; for this says that, where a council claim to recover expenses from a person as being the owner of premises and he is receiving the rent as agent or trustee for another person and has not, and since the date of service of demand has not had, sufficient money in his hands on behalf of that person, his liability is limited to the amount he has, or has had. The council can recover any excess over this only from the person on behalf of whom the agent or trustee is acting.

Another matter worth mention here is that, both in London and elsewhere, any expenses recoverable from an owner by the council may be recovered from the occupier, up to the amount of rent which is due from him to the owner, or which may become due

after the expenses are demanded. In the absence of any contract to the contrary, the occupier may deduct from his rent such payments as have been recovered from him.

The Housing Acts. Finally, it is necessary to refer to certain provisions of the Housing Act, 1936. Section 2 of this Act provides that in any contract, made before or after the passing of the Act, for the letting for habitation a dwelling-house, or part of a house, at a rent not exceeding in the administrative County of London £40 and elsewhere £26 per annum, there shall, notwithstanding any stipulation to the contrary, be implied a condition that the house is at the commencement of the tenancy, and an undertaking that the house will be kept by the landlord during the tenancy in all respects reasonably fit for human habitation.

This condition and undertaking are not to apply where the house is let for a term of not less than three years upon the terms that it be put by the lessee into a condition reasonably fit for habitation, and the lease is not determinable by either party before the expiration of three years.

The foregoing shall not apply to a house situate elsewhere than in the County of London, or a borough or urban district with a population of 50,000 or upwards, the rent of which exceeds £16, if the contract was made before the 31st July, 1923.

Other parts of the same Act deal with the clearance of areas in which the houses are either unfit for habitation owing to disrepair or sanitary defects, or dangerous to health owing to bad arrangement of buildings, or narrowness or bad arrangement of streets; with the redevelopment of areas which contain houses which are overcrowded, unfit for habitation or arranged in a congested manner; with the repair or demolition of individual houses which are unfit for habitation; with the remedying of overcrowding of houses, the removal of obstructive buildings and the provision of houses for the working classes. It would be going beyond the scope of a work on sanitation to describe the provisions in detail, so that readers are referred to specialised books on Housing or to the Act itself.

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